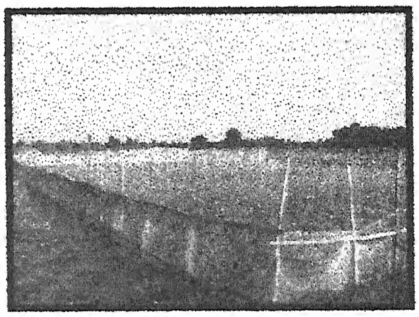
Studies on Biological Productivity in Pahunj Reservoir, Jhansi



Thesis Submitted for the Degree of

Doctor of Philosophy

_in_

Zoology

_by_

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Guide

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I certify that Mr. Mahesh Chand Chauhan has worked at Bipin Bihari College, Jhansi under my supervision, on the topic entitled "**STUDIES ON BIOLOGICAL PRODUCTIVITY IN PAHUNJ RESERVOIR, JHANSI**". It is based on, monthly and seasonal observations on the Pahunj reservoir as mentioned in the synopsis. This work is original and suitable for submission for the award of the degree of Doctor of Philosophy.

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Chapter -1
Introduction

In the context of prevailing agro based economy of our country, the importance of fisheries resources can hardly be overemphasized. The Contribution of fishery sector towards employment, protein production and economy is not only significant but also bears a promise as well as potential for future growth. Abundance of aquatic resources, diversity of fish species, compatibility with other farming systems and capability to utilize organic waste have made aquaculture an upcoming economic activity. Spectacular growth and its potential justifies that this sector needs diversification. Sustainable aquaculture is one of the most productive uses of land and water resources hence faces many challenges from other competing uses of the physical resources and those of environmental concerns. Now it has been realised at the global level that culture is the only way of increasing production from this sector. There is no gainsaying the fact that India is in the same situation and should continue to accord high priority to sustainable aquaculture development.

The fresh water aquaculture resources in the country comprise 2.25 million hectares of ponds and tanks, 1.30 million hectares of beels and derelict waters, 2.09 million hectares of lakes and reservoir,0.12 millions kilometer of irrigation canals and channels and 2.30 million hectares of paddy fields, a portion of which is available to fish culture. The inland fish yield in India has witnessed an eight fold increase in the last four decades from0.22 million metric tonnes in 1951 to 2.20 million metric tonnes in 1996 with a growth rate of as much to 10.74% in 1992. The contribution from Inland sector to the total production has increased from 28.9% to over 44.4% indicating the potential of this sector. To the achievable target of 8 million metric tonnes of fish to be realized by the turn of the century, the estimated contribution from the inland sector would be to the tune of 4.5 million metric tonnes, more than 50% of which is expected to be produced through aquaculture. It must be emphasized that fresh water aquaculture is alone contributing over 1.5 million metric tonnes, accounting to more than 30% of total fish production.

Uttar Pradesh, being a land locked state, possess only fresh water resources with exception of negligible saline waters present in Western region. Total water area available in state is estimated to be about 1.65 million hectares. Out of which 0.7 million hectares is flowing in nature and

remaining 0.445 million hectares in confined area. In confined waters about 0.162, 0.150 and 0.133 million hectares is demarkable as rural ponds, reservoirs and lakes respectively (Anon,1999). In open waters only capture fishery is possible while confined waters can be used for capture and culture fishery. Data on sector wise utilization and productivity is scares. However ponds, lakes and reservoirs get relatively more attention with the result of higher productivity which is 2350 kg/ha/yr in ponds and 119 kg/ha/yr in reservoirs.

Bundelkhand region of Uttar Pradesh lies in central plateau region. It is a predominantly drought prone area and need for stored water has resulted in the construction of a large number of water bodies. Fisheries in this region occupies unique characteristics due to varied geo-physical conditions, located between 23 ^{0} 8'- 26^0 30 N latitude and 78^0 11 - 81^0 30 E with an area of 19264 sq. km. and 879 mm average rainfall. This area has tropical monsoon climate receiving 95 percent annual rainfall during monsoon period only. Scare rain coupled with difficult subterranean water and high summer temperature (47 degree ±4) make this region an unique one. Although this region possesses a well woven network of rainfed rivers, lakes, ponds and canals, the need for stored water for human consumption as well as for other purposes has resulted in the construction of large number of water bodies to store rainwater. As the rivers are rainfed, they drain huge quantity of water during monsoons. Maximum flow of water occurs in few days. During summer discharge becomes almost negligible. In fact this condition compelled the planners to tame all rivers for water storage to ensure round the year availability of water. These water bodies are multipurpose and fisheries is one of them.

Reservoir fishery is essentially a stocking cum capture system and can be classified as : Large reservoirs(above 5000 hectares), medium reservoirs (1000 to 5000 hectares), and small reservoirs (below 1000 hectares). Fish productivity of Indian reservoirs is generally low and present level is 10 kg/h/yr. The potential of reservoir fisheries can be estimated by assuming different level of achievable productivity. Productivity is a function of area, plankton resources, stocking policy, conservation and regulatory measures, number of operating fishermen, efforts put in by the controlling and developing authorities. Reservoirs are men made ecosystem differing

form other water bodies in their origin, trophic evolution, morphometric and edaphic factors, hence their productivity is influenced by climatic, edaphic and morphometric features. The edaphic features such as extent of drainage area, its rate of evaporation and total runoff determine the nutrient load in reservoir. While climate and basin morphometry determine the rate of their utilization. It has been recorded in Indian reservoirs that their fertility depends on catchment area rather than basin soil (Natrajan, 1976).

To establish a baseline for evolving suitable management measures towards fishery management in small reservoirs, the then Central Inland Fisheries Research Institute (CIFRI) initiated investigation on many small reservoirs (Khan, 1997). Studies on hydrobiology, primary productivity, plankton, macrobenthos, macrovegetation, soil characteristics, experimental fishing and biology of commercial fishes have been conducted. Although these studies were made in early eighties but specifically no reservoir from this region was covered under these projects. Therefore, a detailed and comprehensive study has been made to study different abiotic and biotic factors effecting the biological productivity in Pahunj reservoir located in Jhansi district. This work will help to understand the concerned variables for the formulation of management policies for sustainable fish yield on long term basis.

Chapter -2

Material and Methods

Pahunj is a small reservoir with an area of 518 hactares at full reservoir level (FRL) and 55 hactares at dead storage level (DSL) with a maximum depth of 10meters . Required samples were collected from the middle column in central portion of reservoir towards the left bank on monthly basis for one and half year. Water samples for various analysis were collected by locally made sampler.

Meteorological data was obtained from Indian grassland and fodder research institute situated in the viscinity of Pahunj reservoir. Records of irrigation department were used to study storage and movement of water. The catch composition of fish, and year wise yield, corresponding efforts and revenue figures were collected from fisheries department, Jhansi.

1. Physical parameters : (a) Temperature ; this was recorded with an ordinary thermometer (accurate upto 0.01^0 c) at the time of sampling (b) Transparency (Secchi Disc Method); the disc consists of a circular metal plate of 20 cm in diameter. The upper surface of which is divided into four equal quadrants each of them being painted black and white alternately while the lower side of the plate is painted black to eliminate reflection of light from that side. The disc is lowered with the help of a rope into the water and the depth (d1) at which it disappears is noted. Now the disc is lifted slowly and the depth (d2) at which the disc reappears is noted. Transparency=d1+d2/2

(2) Chemical parameter : (a) pH (Colorometric method), the principle of this method is to develop colour in the sample with one indicator dye and to compare it with the colour of standard disc. Mixing of 10ml sample in clear glass tube with 0.5 ml of indicator, develops some colour which can be matched against the colour disc in the comparator. To know which indicator is suitable a preparatory test with universal indicator was made to get correct pH values.

(b) **Alkalinity :**Generally three types of alkalinity are found. They are OH^- (hydroxides), CO_3^{-2} (Carbonate)and HCO_3^- (bicarbonates)which can be determined by using two different indicators namely phenolphthalein and methyl orange. The alkalinities so determined are called 'P' and 'M'.However, for all practical purposes, methyl orange alkalinity M.O.A. gives a measure of the acid combining capacity of water. Reagents used are (i)0.02 N H_2SO_4 : 30 ml of conc H_2SO_4 (Special Grade 1.84) is diluted to 1 litre. It gives 1N H_2SO_4, 20ml of this solution diluted to

1litre is approximately 0.02 NH_2SO_4 (b)0.02 N H_2SO_4. (ii) Standard 0.02N $NaCO_3$: Take 5.3 gms of anhydrous Na_2CO_3 in 1 litre of distilled water. It is 0.1 N Na_2CO_3. (iii) Phenolphthalein indicator. Procedure followed was, a) Phenolphthalein alkalinity (P) : By mixing of 50 ml sample with 2 drops of phenolphthalein indicator. If sample remains colourless 'P' is absent. Appearance of pink colour confirms its presence. Titration of this solution with 0.02N H_2SO_4 until the pink colour disappears. Calculations according to following formula gives 'P' values. P (as ppm of $CaCO_3$) = No. of ml of 0.02NH_2SO_4X 20. b) Methyl orange alkalinity (M) : Proceed in the same way using methyl orange as indicator at the end point the colour changes from yellow to faint orange.

(C) **Free Carbon-di-oxide :** Reagents used were N/44 NaOH; 4 gm of NaOH dissolved in 1 litre of water, gives 0.1 N NaOH. Standardise this solution with 0.1 NH_2SO_4 using phenopthalein indicator. 100 ml of this solution diluted to 440 ml gives N/44 NaOH. Procedure followed were, take 50 ml of water sample in a conical flask and add 2 drop of phenopthalein indicator if the colour of water turns pink, there is no CO_2 present. If the water is colourless, add drop by drop with the help of a graduated 10 ml pipette with gentle stirring till the colour turns pink. Quantity of CO_2 is No. of ml of N/44 NaOH required X 20 = ppm of free CO_2.

(D)Dissolved oxygen (Winkler's method) : This method is based on the oxidation of manganous sulphate in alkaline medium by the oxygen present in the sample into mangnese oxyhydroxides [$Mno(OH)_2$]. This compound on acidification with concentrated sulphuric acid liberates oxygen which in turn releases equivalent amount of Iodine from potassium Iodide. This Iodine can be titrate with sodium thiosulphate using starch indicator. From the amount of Iodine liberated the amount of oxygen originally present in the sample can be calculated. Reagents are i) Magnous sulphate, 480 g of $MnSo_4$, $4H_2O$ or 400 g of $MnSO_4$, $2H_2O$ dissolved in distilled water and made upto 1 litre. ii) Alkaline Iodine, 700 g of KOH or 500 g of NaOH and 135 N of NaI or 150 N KI in distilled water and diluted to 1 litre. iii) Sulphuric acid concentrated iv) Starch solution, Make an emulsion of 2 g of starch in distilled water. Add this emulsion with 350 ml of boiling water. v) Standard Sodium thiosulphate, 24.82 g of Sodium thiosulphate dissolved in distilled water and

diluted to 1 litre of distilled water, it gives 0.1 N $Na_2S_2O_3$. Standardise this solution with 0.1 N $Na_2S_2O_3$ solution. 64.904 g dissolved in 1 litre. 125ml of this solution diluted to 1 litre gives N/80 $Na_2S_2O_3$.

Procedure : Mixing of 250 ml sample with 2 ml of Manganous sulphate and 2 ml of alkaline iodide regent causes precipitation. Allow the precipitate to settle for some time leaving supernatant above the precipitate. Carefully removed the stopper and add 2 ml of concentrated sulphuric acid followed by stirring untill the precipitate is dissolved. 50 ml of this solution is titrated with standard thiosulphate (N/80) to pale yellow colour. Add 1 to 2 drop of freshly prepared starch solution and continue the titration to the first disappearance of blue colour. Dissolved oxygen (ppm) + 4 X No. of ml of $Na_2S_2O_3$ solution (1 ml of $Na_2S_2O_3$ =0.1 mg O_3).

(E) Dissolved phosphates : Reagents used are i) Sulphuric acid (50%) ii) Ammonium molybdate (10%) iii) Acid ammonium molybdate 15 ml of 50% H_2SO_4+ 5ml of 10% Amm.molybdate iv) Stannous chloride v) Standard phosphate (1ml=0.01P); 4.338 g of monobasic phosphate (KH_2PO_4) in 1 litre distilled water. Take 50 ml of the sample in Nessler's tube add 1ml of acid molybdate and 2 drops of stannous chloride mix gently, a blue colour develops. Prepare a number of standard solutions of phosphate in the Nessler's tube and add 2 ml of acid molybdate and 2 drops of stannous chloride. Match the blue colour of the solution with the standards. Number, of ml of standard phosphate X 0.01 X 20= ppm of P. (The method is based on the principle that phosphorus develops blue colour of phospho-molybdic acid in presence of acid molybdate and stannous chloride).

(F) Nitrogen (Nitrate-nitrogen) : Reagents used are a) Nessler's solution b) Standard NH_4CL solution : Dissolve 3.816 g of anhydrous ammonium chloride in ammonia free distilled water and diluted it to 1 litre (1 ml = 1 mg N), 10 ml of this solution to 1 litre with ammonia free distilled water (1ml =0.01 mg N). c) Ammonia free distilled water d) Magnesium oxide e) Devard's alloy. Distillation method, Place 50 ml of water sample in a Kjeldahl distillation flask. Add approximately 0.5g magnesium oxide followed by 50 ml ammonia free distilled water and distilled in a Kjeldahl distillation unit. Collect 40 ml of the distillate. To know the amount of

nitrate cooled the distillation flask after ammonia distillation. Add small amount of Devard's alloy to the contents of the flask followed by 50 ml of ammonia free distilled water. Distil the mixture in the similar way. Nitrate is reduced to ammonia by the Devard's alloy. Collect 40 ml of the distillate and make up to 50 ml and keep it in Nessler's tube. This gives the nitrate present (b). Prepare a number of solutions of different nitrogen content from the standard solution. Added 1 ml of Nessler's reagent to each and also to the two distillates. Match the colour with the colour of the standards. No of ml standard for (B) X 0.01 x 20 =ppm of NO_3^-N.

3. ESTIMATION OF PRIMARY PRODUCTIVITY : The concept of " Production" is the total amount of organic matter produced in a given space during a given period. However, sometimes it has often been confused with the concept of standing crop. Odum (1971) defined basic or primary productivity of an ecological system, community, or any part there of, as the rate at which radiant energy is stored by photosynthetic and chemosynthetic activities of producer organisms, mainly green plants, in the form of organic substances which can be used as food. The primary productivity was estimated by oxygen method : Gaarder & Gran (1927) calculated the photosynthetic activity from amount of oxygen produced by phytoplankton during a given time. Water samples should be collected from regular depths or at percentage of surface illumination (100%, 75%,50%,25%, 1%) with locally made sampler of 2 litre capacity. Four ground stoppered bottles were prepared by polishing or painting the clear corning, with black enamel paint. Add winkler- A and winkler -B (0.5 ml in 125 ml sample) in the Initial bottle. Sets of ' light and dark' bottles were suspended in situ at the original depths where from the water sample was taken. They can be suspended from 10 am. - 4 pm. After 6 hours, the oxygen content of each bottle was measured by the Winklers method. From the difference between the initial and the final concentration of oxygen, net production was obtained in the transparent bottles (L-I) and respiration in the dark (L-D). However, it was noted that the decrease of the oxygen in the dark bottle resulted from the consumption of oxygen is not only through respiration of phytoplanktons and other organisms, but also through the decomposition of organic debris in water. It should also be noted that the condition inside the dark bottles favours the bacterial growth. These

bacteria also liberate dissolved oxygen and the total oxygen in the bottle increased. If this increase is accounted for calculations it leads to the over estimation of gross production. Oxygen estimated by Winker's method is used for the calculating primary production. P. production (mg C/l)= O2(ml) X 0.375, PQ is Photosynthetic Quotient = 0.375. O_2(ml) =I -D Respiration (In respiration, instead of PQ, RQ is used, which is generally equivalent to 1) L -D Gross production, L-T Net production.These data are convenient to gm of oxygen per cubic meter by multiplying the numerator and denominator by 1000. mg C/m3 = mg C/l X 1000. Primary productivity (mgC/ m3/hr) = O(ml) X 0.375 X 1000/PQ X No. of incubation hrs, plankton community respiration (mg oxygen consumed per hr) = I - D/24

(4) **Plankton analysis :** Plankton were collected by truncated cone shaped net made of bolting silk or orgendia cloth. Bolting silk is the best material for a plankton net and No. 25 standard grade was used for it. This has a mesh size of 0.064 mm (200 meshes per 2.54 cm). The upper broder circumference (30 cm) of the net remain attached to a brass ring with a handle and the lower narrow circumference (9.2cm) is fixed to the mouth of a collecting tube or bucket. 100 liter volume of water usually filtered through it . For any shallow depth of water body, the surface plankton was collected by a mug of know volume and filtered through as plankton net of standard specification. Plankton samples were immediately preserved in 5% formalin just after collection. The volume of the plankton was measured after proper settlement. Sometimes a part of the drop was also examined and by proportionately the entire drop was estimated. Plankton analysis was done by using sedge wike rafter counting cell. Plankton concentrate obtained from the plankton sample was used for estimation. The concentrate is transferred to counting chamber and ten square can be counted. The number of plankton in terms of genera, species etc. per liter of original sample was determined using the formula. N= A X 1000 X C / L. Where N = mean number of plankton per counting cell C = volume of concentrate and L = Volume of original water sample.

(5) **Periphyton Analysis :** The periphyton sample was analysed by the sedge wike rafter counting cell by the method mentioned for the plankton analysis.

(6) **Fish stock assessment :** The maximum sustainable yield (MSY) which is considered to be the biological optimum yield was estimated by means of the Schaefar (1970) models, using time series data on catch and effort. The models take account of the fact that the yield per unit effort (Y/f) is a monotonically decreasing function of fishing effort (f), expressed by equation.

$$\text{shaefer}: Y/f = a-bf \quad (1)$$

$$\text{Fox}: Y/f = \exp^{a-bf} \quad (2)$$

so that the absolute yield (Y) is a parabolic function of ' f '

$$Y = af-bf^2 \quad (3)$$

$$Y = (e \times p^{a-bf})f \quad (4)$$

$$dy/df = a-2bf...$$

At f corresponding to MSY (i.e.,) f_{msy}, dy/dy =0, i.e.,

$$dy/df = 0 = a-2bf_{msy}$$

$$\backslash \quad f_{msy} = a/2bf \quad (5)$$

Since MSY is obtained at f msy, the relation for its estimation may be derived substituting equation (5) in equation (3)

$$MSY = af_{msy} - b\, f\, 2\, f_{msy} \text{ or}$$

$$MSY = a(a/2b) - b(a/2b)2$$

$$MSY = a^2/4b \quad (6)$$

MSY and f_{msy} were estimated according to fox (1970) by the following expressions.

$$MSY = (1/b)\, e^{a-1} \quad (7)$$

$$\text{and } f_{msy} = 1/b \quad (8)$$

Estimation of maximum economic yield (MSY) starts with the derivation of the price function, i.e., price per unit weight of fish (1kg), p, as a function of yield or supply, y. for commodities, where price is determined by market forces, p is a monotonically decreasing function of Y as shown below.

$$p = a-by \quad (9)$$

$$p = tr-tc \quad (10)$$

profit p is is the difference between total revenue from yield and the total cost (TC) for generating that yield.

$$TR = y(a-by)$$

$$TR = ay - by^2 \ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

TC = cy, where C is the cost per unit weight of fish of fish caught (1 kg), equation may now be rewritten as,

$$p = ay-by^2 -cy \ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

since p is maximum at MEY, i.e. the crest of the curve for equation (10), where the slope is zero, may be differentiated with respect to Y, in order to estimate may ;

$$dp/dy = a- 2by-C;$$

$$\text{at MEY, } dp/dy = 0 = a-2b\,(MEY) - C,$$

$$\text{Thus } MEY = (a-c)/2b \ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

At MEY, the yield equation (3) takes the from,

$$MEY = a\, f_{mey} - bf^2_{mey} \ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

$$bf^2\, may- af_{mey} + (MEY) = 0 \ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

$$f_{mey} = (a \pm \sqrt{a^2 -4b\,(MEY)}\ /2b \ldots\ldots \quad (16)$$

Estimation of wet biomass of fish has been made by assuming 1% conversion from primary to tertiary biomass provides an alternative estimate of tertiary biomass to compare with that computed from catch and effort data. Wet biomass of fish has been obtained by multiplying tertiary production in terms of carbon (i.e. 1% of carbon at primary production) by a factor of 7.47.

Chapter -3

Meteorodynamics

A. Observations

B. Discussion

A. Observations

Water movement : Pahunj is a multipurpose water reservoir specially meant for irrigation and drinking water supply for adjoining Jhansi city. It is a rainfed river cum reservoir hence receives water only during rains. Adjustable iron gates lie over mansonery dam for the elevation of water level. Draining of stored water during rabi crop decreases water level below these gates making them temporarily useless .These gates remain flat until the month of next September (post monsoon) when required again for elevation of water level. During heavy rain period for July to mid September, this flattening of gates and opening of sluice gate make water out flow easy for drainage of excess water. This uninterrupted flow of water creates riverine condition in reservoir for a limited duration. Fast moving water flushes the reservoir bed and carry whatever goes with it. Closing of sluice gate and erection of iron gates in mid September slowdown water movement due to elevation of water level from 768ft to 737ft and remains at same upto November. Water outflow for irrigation of rabi crop takes place through a canal of 8Mcft capacity. This outflow seldom exceeds the lowest limit (LSL738ft) marked for drinking purpose. Drinking water out let is another properly designed structure which allows slow intake of filtered water .Consumed water get supplemented upto a limited extent from other reservoirs built at upper reaches on this river. This unseasonal supplementary inflow is always calibrated one and never exceeds the FSL capacity so the impact of water movement remain confined to impoundment area only . Another source of inflow are city drains which continuously brings in sewage, quite slowly and neither create current like situation nor increases water level of any significance .This water body normally follow above mentioned water receipt - expenditure cycle annually.

Reservoir Sediment and desiccation : Jhansi region, being a part of central plateau, black cotton and red clay soil, rocky bottom and small hillocks are predominant here. Pahunj reservoir was built about a century ago during British era . Since then continuous deposition of organic matter and silt had converted the reservoir bed into black cotton like soil . Reservoir bed is completely clear of trees and wooden logs but boulders and naked rocks lie exposed intermittently. As a result of usage, water area get constricted to DSL by the end of march. This receding of

water and high summer temperature completely desiccate the exposed reservoir bed where grasses grow out but the rising temperature of May, June dry them. This period from April to Mid July (Dry spell) play a critical role in the life cycle of certain species such as shallow water species , shore area species, benthos and macro-vegetation.

Water transparency / turbidity : The Sacchi transparency varied from 18 cm to 85.5 cm. Minimum Sacchi values were recorded during the month of July ' 96 before rains and minimum was recorded in August 1996. Month wise values show increase from August (22.5 cm) to December (58.3 cm). In winter season lowest values (53.5 cm) were recorded in March 1995 and again it increases till rainfall. Thus two cycles of up and down were seen. First decline is not so prominent as second one observed during monsoon period (Table 30).

Thermics : Determination of temperature was carried out at four different locations from June 1995 to November 1996 on monthly basis. During this period six hourly observations were recorded to observe diurnal variations. Temperature at water surface ranged from 8.5°C to 36°C while air temperature ranged from 4°C to 48.5°C, minimum water surface temperature 8.5°C was recorded in January' 96 with lowest air temperature 4°C also. Maximum water (31°C) and air temperature (48.5°C) were recorded in June 1996. In January ' 96 water temperature (8.5°C) was above the air temperature (4°C). Except the small variations water temperature fluctuation was always little behind air temperature. During winter season lowest temperature varied from 22°C at 14hours and 8.5°C at 5.30hours. Air temperature ranged from 30°C to 4°C for same date and time. Maximum temperature values were recorded in the month of June 1996 from 36°C to 24°C at 14 hours and 5.30 hours. The corresponding air temperature ranged from 48.5°C to 31°C. Water temperature was followed closely by air temperature. Summers were exceptionally hot (48.5°C) due to peculiar geo-climatic conditions and local factors such as absence of trees, open flat surface and stagnation of water. Highest water temperature 36°C was within tolerance limits. Summer conditions were broken up on the onset of monsoon period as soon as reservoir received rain waters. Season wise grouping of data (Table 2) show that temperature is relatively uniform between 30°C to 20°C in winter and sharply increases above 30°C in spring due to

increased day length, clarity of water and deeper penetration of light. It further increases with the approach of summer due to longer period of insolence and direct angular radiation from sun.

Rainfall : Annual rainfall data has also been recorded and given in table 3. Average values from 1989 to 1997 was 823.45mm. During this period rain fall was normal except in 1994 - 95 season when it came down to 566.9 mm. Less rainfall put this region in subtropical zone (medium rain fall). It never exceed above 1000mm mark in any single year but these quantities were always adequate enough to fill the impoundment area. Rainy days in this region are not beyond 60 days in a year. Even within these 60 days effective precipitation take place in two to three weeks only. Some times shallow westernly depression causes one conspicuous but short rainy spell in winters (68 mm). Post monsoon rain extends upto first week of October. Monsoons generally become active in late June or early July and after few showers dry spell of 20-25 day occur. In a typical case of 1996 total rain received was 903.5 mm in 47 days from April 94 to March 1996 .Monsoons arrived on 4th June i.e. 26th standard meteorological week .But it became active only in 4th week of July (30th standard meteorologically week) and lasted in 1st week of September. The overall rainfall pattern is very erratic and uncertain which may be vitally responsible for creating scarcity of water.

Relative humidity : Relative humidity coincide with the rate of precipitation (Table 4). Minimum and maximum Relative humidity occurs in the month of May and September respectively. Observed values for the month of may 1997 were below 30% and for Sept. 1993, 97%. Higher relative humidity values exist only from late June to September, Jhansi being a draught prone area remaining months of the year experience less humidity particularly in winter months when vegetation wilted down.

Rate of evaporation : Daily evaporation rate range from 5.32 mm (93-94) to 6.13mm (95-96). Average being 5.7mm/day of the entire study period from 89 to 98. Evaporation rate fluctuated with the atmospheric temperature and relative humidity. It remain highest in June (summer) and lowest in December (winter). It is evident from the table 5, that highest evaporation (13.9mm) was observed in the month of may (95-96) while lowest evaporation rate was observed 1.1 mm/

day in December 95-96.

Wind velocity : Recorded wind velocity ranged from 2.78 km/hr to 6.3 km/hr. Monthly trend of wind velocity progressively increases from January to June (Table 6). Exceptionally high wind velocity (16.8 km/hr) occurred in 28th July'95 and 16.8 km/hr on 22nd June /1996, October to December was lean period with less wind activity.

B. DISCUSSION

Water movement is one of the critical factor shaping the biocoenosis because of its direct effect on substratum. Current is an extremely variable factor as it depends on rainfall however, sudden spates in this reservoir usually don't occur except very occasional heavy down pour during monsoons. Strong current carry away silt and leave only heavy objects while weak current allow settlement of silt at bottom for the growth of benthos and mud. Macan (1974) observed that fauna and flora tend to differ in each current speed and flow is not necessarily an unfavourable factor. Moreover, current affects the bottom and micro-organisms more acutely. Depth, current speed and substratum together act in combination and make a cohesive impact on distribution of biotic communities. Water current above critical limits usually disturb the established fauna.There are evidences (Macan,1974) that the number of certain species increase with speed to reach a peak that was different for each species and then decline with further increase in the rate of flow.Water current is specifically important for Indian major carps which don't breed in stagnant water. Continuous inflow of water with a certain speed and for adequate period is essential for breeding of these carps. In the present case these condition usually appear in late July or early August when these fishes breed. Studies related to water movement suggest that it makes a multidimensional impact on the stability and productivity of this ecosystem.

Nature of a substratum varies with the properties of mother rock. Many factors contribute in the formation of bottom where regional variations play a decisive role. Important factors are age of water body ,size, latitude ,climate of locality ,soil and underlying rock formation .The gradient and type of substrate are major factors as they govern the water movement. In reservoirs these fluctuations are usually greater. Among four main recognised geological systems the area around Pahunj is recent one. It is represented by large scale alluvial deposits in the north, containing sand, silt and clay (Tyagi, 1997). Pahunj is now almost one hundred year old and gradual silting had converted it into a flat plate like water body except a central ridge which is little deeper due to more speed of water current as it don't allow silt settlement. Draining out of very little water exposes a large part of reservoir bed for desiccation. Recurring desiccation of these parts changes

the composition of flora and fauna annually as describe in chapter 4. Beside the physical depth of water , desiccation also imposes certain changes in the bottom soil which make an unavoidable impact on the release of nutrients. Growth of vegetation and plankton population are regulated by incoming solar radiation which is related to water depth ,available nutrients and quality of water. In the light of above discussion, it is worth to be mentioned here that shallow zones support better primary productivity as observed in present case.

Turbidity is a degree of opaqueness produced in water by suspended particulate matter. While the nature of materials contributing to the turbidity is responsible for colour quality, concentration of the substance determines the transparency of water by limiting transmission within it. Turbidity is not a uniform parameter. Seasonal changes in aquatic flora, release of organic matter and incoming silt from catchment area on account of precipitation during monsoon are the basic controlling factors. Several workers have reported turbidity/transparency mean values ranging from 1.8 cm to 28.5 cm in Rihand (Natrajan 1981), 112.1cm in Ghandi Sagar, 107cm in Bhawani Sagar and 66.70cm Bacchra (Pathak, 1997) .Khan & Khan (1985) reported 16.6 to 85.1cm in Sheikha lake and 16 to 32.8 cm (Haque et.al, 1989) in a pond at Aligarh.

Turbidity is important for two reasons. Firstly it reflect the process of sedimentation of silt which act as a link in entire series of hydrophysical and chemical process in reservoir. It also indirectly indicates the degree of stability of animal habitat. Secondly the penetration of light is directly related to transparency which governs photosynthesis. Observed Sacchi values in Pahunj reservoir may be attributed to several factors as mentioned by earlier workers. Monsoon rains particularly first rains bring silt and dust which drastically decreases transparency till the month of October. Reduction in the incoming sun radiation in winter again reduces it. This trend get reversed with the approach of summer and continues upwardly till rain occurs.

Thermal properties of water and the attending relationships are important factors in maintaining the fitness of aquatic environment. Specific heat of water is among the highest of all substances. This absorption capacity account for many features. Water has unique characteristics of reaching maximum density at 3.98°C. These two factors are important in considering the

thermal dyanamics of reservoir waters. Lamberts's Law explains that light absorption increases exponentially with the light path and over 50% of radiation is absorbed within a depth of 2m. This part of radiation is our main concern which causes heating of water. Sun is the source of heat and its effects depend upon angle at which it strikes. Heat is lost by evaporation which varies with the amount of moisture in air and speed of wind. There may also be direct exchange of heat between air and water and between water and substratum.

Pathak (1997) has reported average maximum water temperature of various reservoirs (Ghandhi Sagar- 22.5°C, Nagarjun Sagar- 27.5°C, Rihand- 24°C, Bhavani Sagar- 25.8°C, Bachchra- 26.7°C and Aliyar- 26.2°C). At present Pahunj shows average for maximum values around 33.3°C. Slightly higher value may be attributed to its location in central plateau region at 23^0 8'-26^0 30N latitude. Similar values (33°C) were reported by Srinivasan (1969) for central Indian waters. Hence, recorded values are in conformity with other works in same geo-climatic conditions.

Another important feature in determining water temperature is its total volume. Surface temperature of shallow fish pond reaches up to 32.6°C (Khan and Khan, 1985). Its fluctuation was always a little behind of air temperature. It is obvious that more water to be heated, the slower is the heating process. Pahunj reservoir is basically a multipurpose storage body. Drawing of water for irrigation and drinking purposes continuously decreases water volume making more susceptible to environmental changes.

The temperature of water varies throughout the year and remains below air temperature in summer while It rises only in winter (table 2). Summer of this region are notable for fine sunny spells right from May to October . Thermograph (Figure 3) shows that highest temperature difference was not reached during hot spell when there was not much water except in September. This difference was probably due to heat from warm surface layer of soil and reduction of cooling by evaporation owing to high humidity. For comparison of aquatic environment with respect to organism, knowledge of heat income and budget is a useful tool. Since sun is the only source of heat income, the annual heat budget required into account the total quantity of heat takes to

warm water from winter lowest to maximum summer temperature. Hence temperature regime of a reservoir is one of the most important factor in determining life process of organism. The influence of water temperature on the course of life cycle of fishes is multifaceted because the rate of maturation of spawners, the period of spawning, incubation period of eggs and development of food organisms depends upon optimal temperature for feeding and condition of available food. The water temperature of reservoirs in north India are lower than that of south. Reservoir in temperate region often develop thermocline with the formation of epilimnion, metalimnion and hypolimnion. But in tropical regions no such thermal stratification occurs. Although some ill defined thermal gradient has been reported by Srinivasan (1969) in few south Indian reservoirs, Patil (1989) reported unstable thermocline in Waghi Nala in Sagar district(MP). Hutchinson (1967) classified lakes on the basis of mixing. Pahunj reservoir shows properties of oligomictic lakes. It implies warm lakes where water temperature is considerably higher than 4°C. Circulation of water occurs rarely at irregular period and found typically at low elevation in tropical zone.

Reservoir fisheries is gradually becoming culture fisheries so the knowledge of temperature regime is essential for better productivity (Jhingaran,1987) . According to him Indian major carps usually thrive well in a wide range of temperature 18.3°C to 37.8°C. According to Das (1945) the upper lethal temperature limit of air breathing fishes like *Anabas testudineus, Channa punctatus, Heteropeneustic fossilis and Clarias batrachus*, Fishes of other groups like *Puntius ticto, Rasbora daniconius and Mystus tangra* is little higher (41°C) than all other species found in Pahunj reservoir.

Any form of moisture which results from condensation is covered under precipitation. The commonest and most significant type is ofcourse rainfall. In Bundelkhand region it is mainly convectional. The mean annual rainfall varies from 740mm in north west to 1235mm in south east prt (Tyagi, 1997). It implies that initial catchment areas of mentioned rivers receives more rainfall as the flow is from south to north. With the onset of monsson rains, generally from middle of the June high temperature comes down abruptly. This abrupt change of climate induces sudden spurt of vital activities in all spheres of life. Relative humidity during monsoon ranges between

70 to 80%. Humidity has a physiological significance because it determines the efficiency of water evaporating mechanism. It is also necessarily an important factor for the amount of precipitation any locality may receive. In Bundelkhand a large period retain less humidity, hence amount of precipitation is also low.

Wind is always the results of a difference in pressure between two areas. Normally greater the difference in pressure, the greater is the movement of wind. Air density and friction on the ground are other factors. This region experiences usually less intense winds. Since the climate is overall weather, it follows that the elements of climate are the same as those of weather. The element may be sunshine, temperature, moisture, pressure and winds. The term moisture embraces all forms of condensation and precipitation as well as humidity. The prominence of individual factor varies with location and time of year. Plateau climate for example in Bundelkhand is distinctive because of altitude, higher in density of insolation and terrestrial radiation.

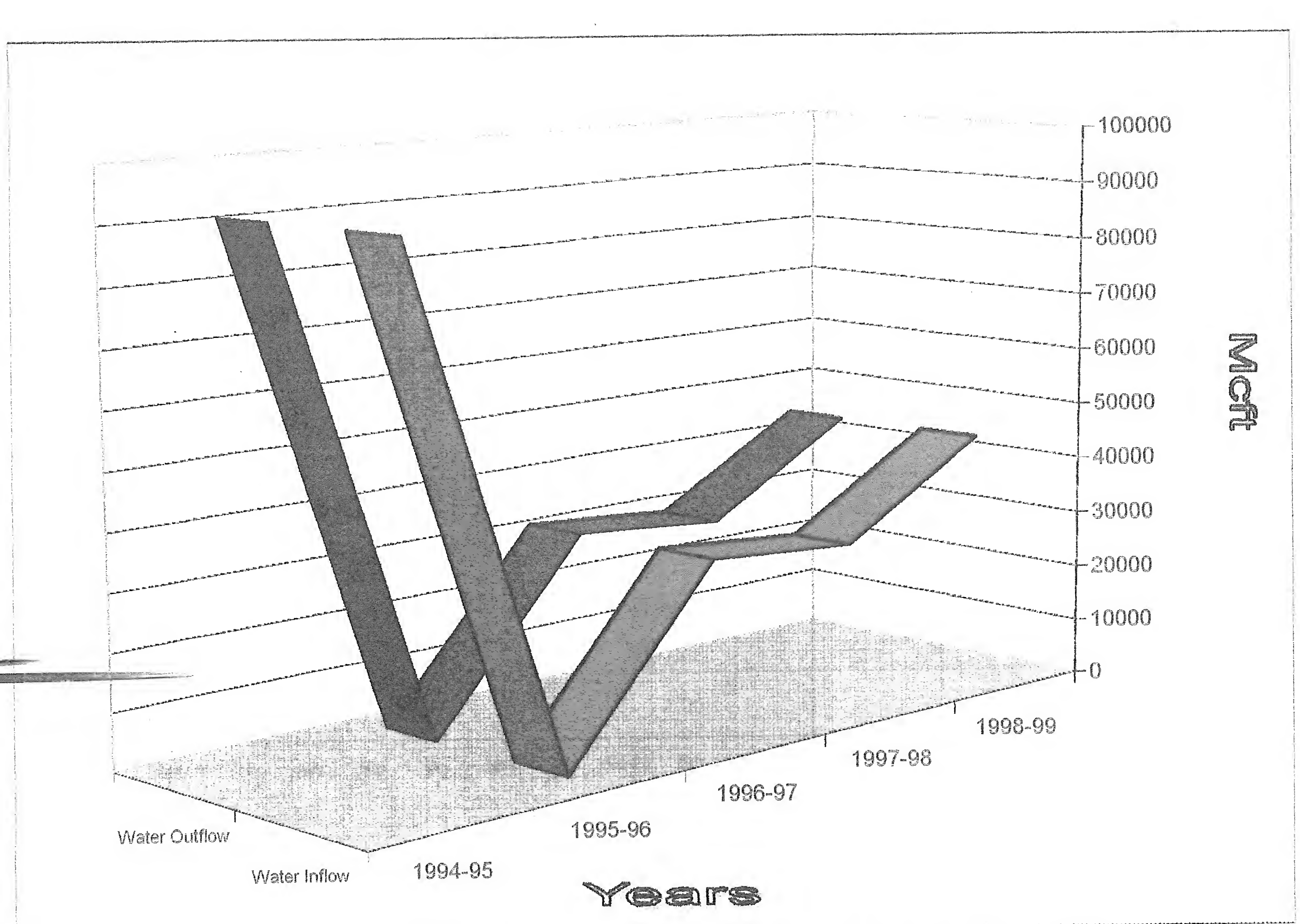


FIGURE : 1 - Yearly water inflow and outflow in Pahunj reservoir.

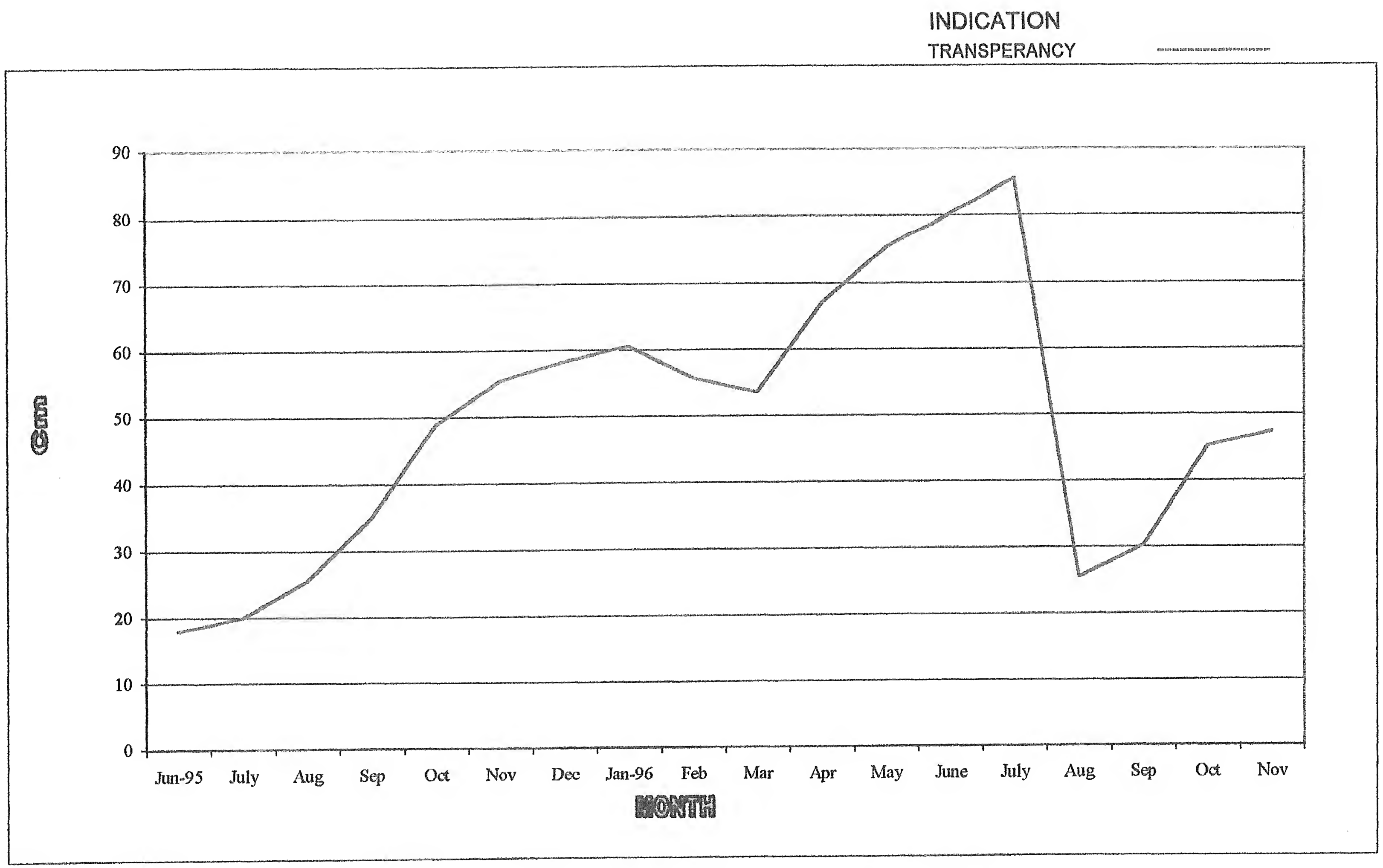


FIGURE 2 : Seasonal variation of Transperancy in Pahunj Reservoir.

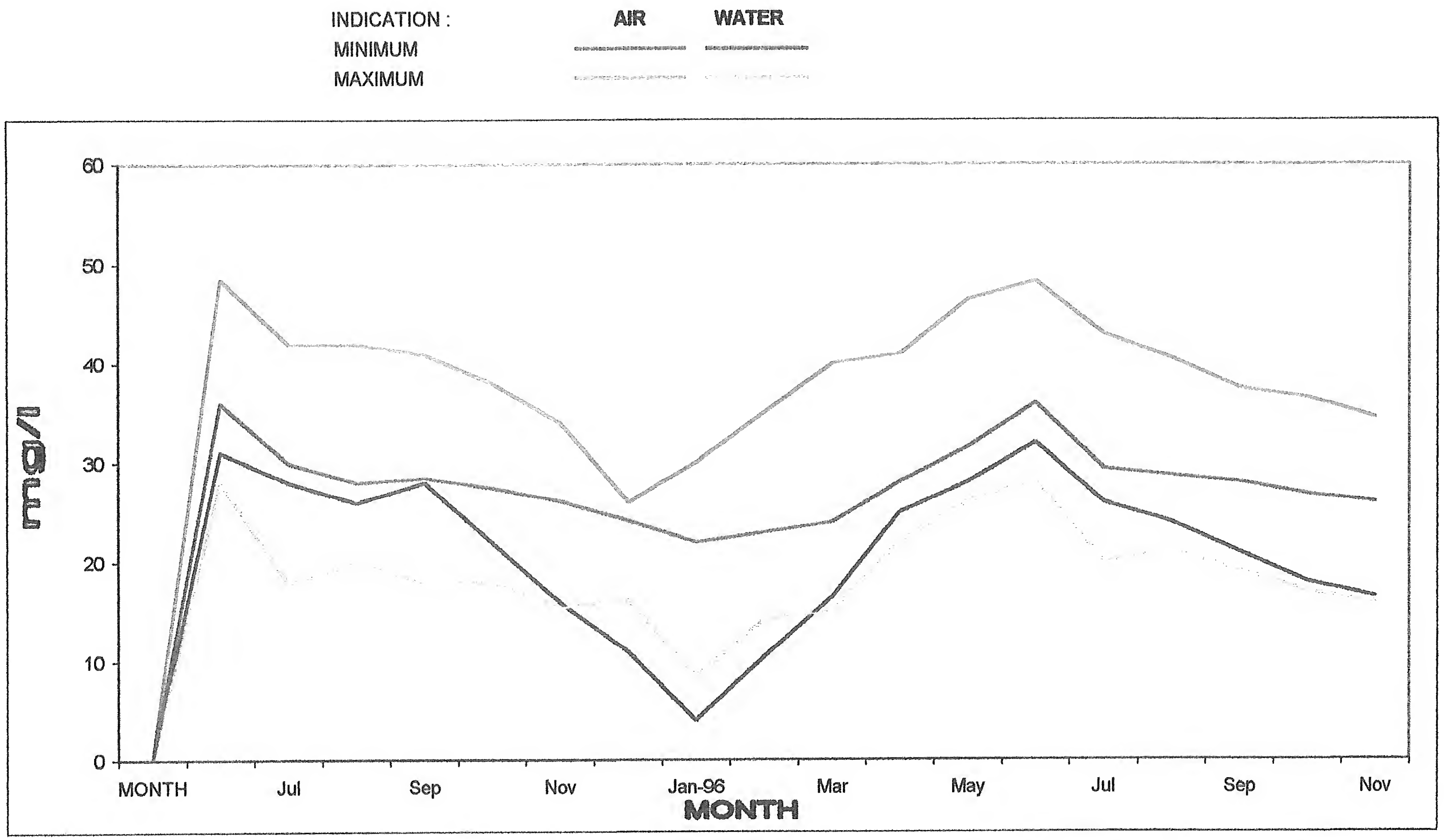


FIGURE - 3 : Seasonal variation of air and water temperature in Phaunj reservoir.

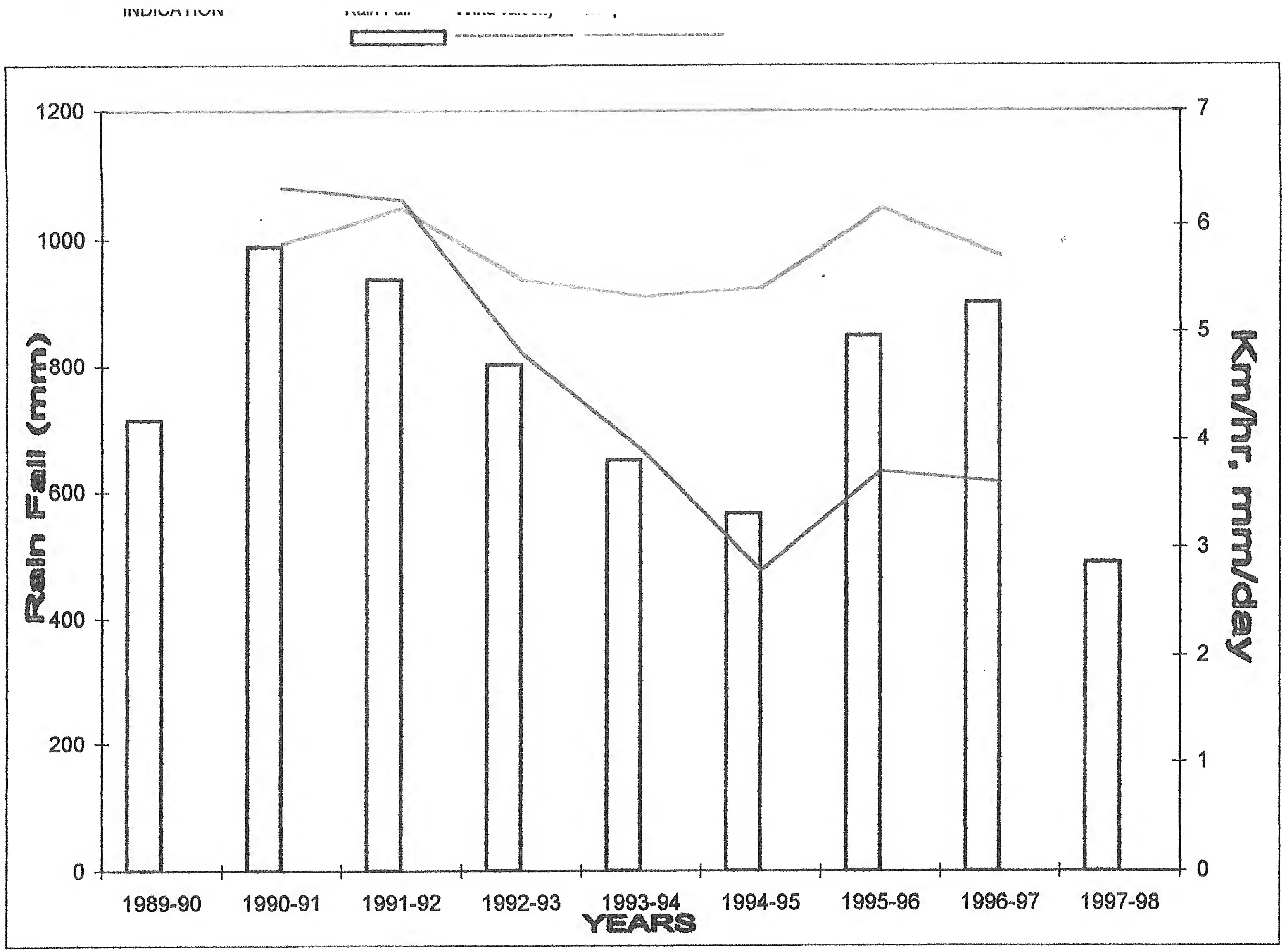


FIGURE- 4 : Yearly rain fall, average wind valocity and evaparation rate in Jhansi district.

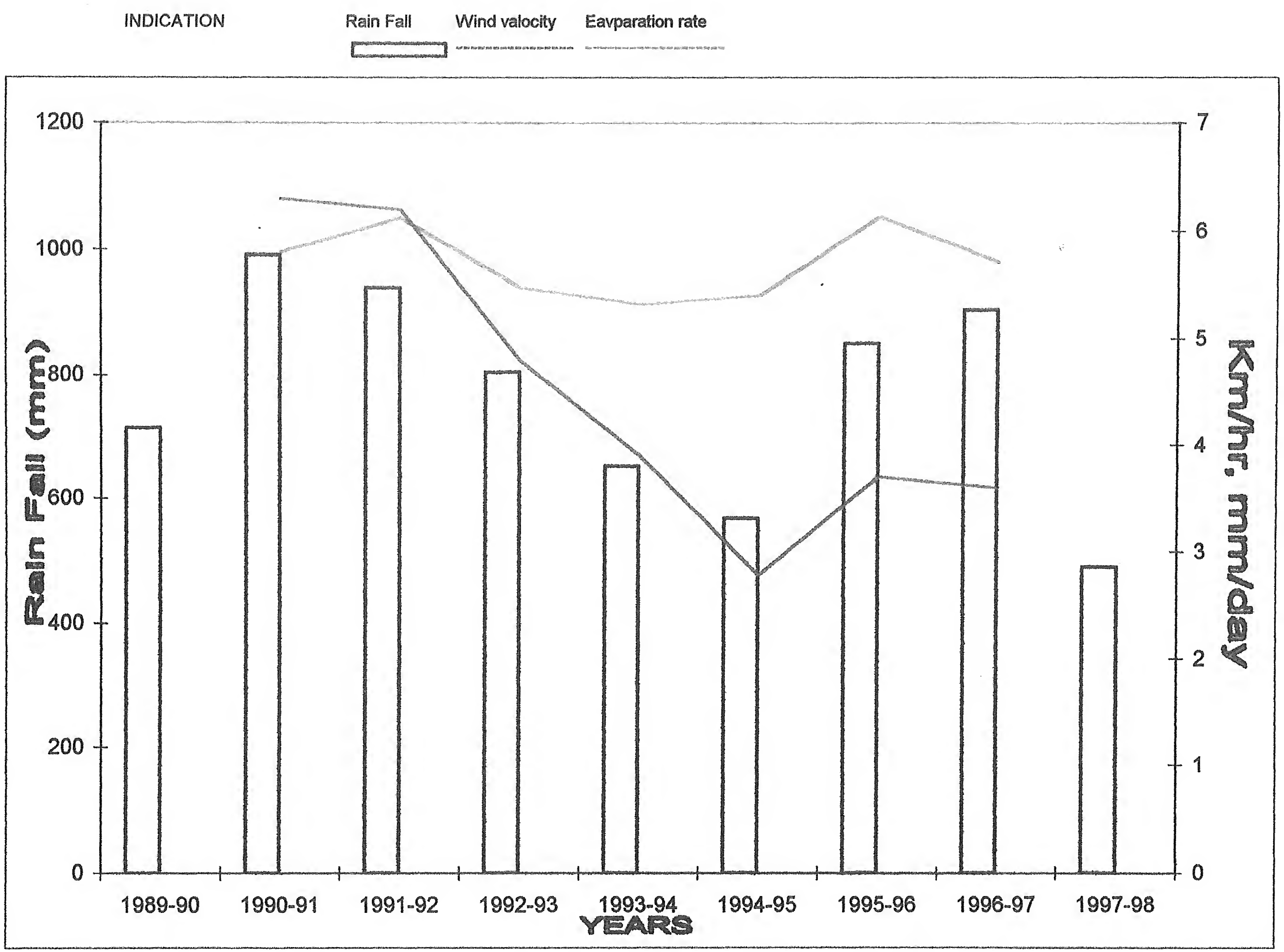


FIGURE- 4 : Yearly rain fall, average wind valocity and evaparation rate in Jhansi district.

Chapter -4

Chemo Dynamics

A. Observations

B. Discussion

A. Observations

pH : The mean value for pH ranged between 6.8 to 9.2 and showed no significant variation in column. The average pH values for surface water was highest (9.2) in winter (December) followed by summer and monsoons period. pH value at all stations are found within permissible limits (6 to 10). Reservoir water remained near neutral to alkaline throughout study period. Winter increase in p^Hvalue can be attributed to photosynthetic activity and increased biomass. Diurnal change for pH were recorded at six hourly intervals (Table 7). Generally it was more in morning and less in the evening . The range of Variations were 7.0 to 9.2, 7.2 to 8.8, 7.6 to 9.2 and 7.2 to 8.8 in four series of diurnal variation for winter, spring, summer and monsoons respectively.

Dissolved Oxygen : Dissolved oxygen concentration in the surface waters fluctuated between 1.8 mg/l to 8.9 mg/l (Table 8). Average values for dissolved oxygen were recorded (8.9mg/l) in the month ofNovember '95. Average values remained well under the permissible limits and critical points never reached i.e. complete depletion and saturation (16 mg/l). Morning values were always lower than afternoon values having its peak around 14 hrs to 17 hrs. Values recorded exclusively for cloudy days (2.5 to 5.5 mg/1) do not coincide with routine values. Diurnal variation show deflection of 6.5 mg/l while seasonal deflection was also similar 6.5 mg/l.

Free Carbon Dioxide (Co_2) : Free carbon dioxide varied from zero mg/l to 5.0 mg/l. Absence of carbon dioxide was recorded in all months around 14 hrs and 17.30 hrs except February'96 and June'96 evenings. Highest value 5.0mg/l was recorded in September'95 at 10hrs. Generally free carbon dioxide was higher in morning hours. Monthly data shows higher values in the summer season due to decreased water level and decaying of vegetation. With the onset of monsoons and consequent inflow of rain water it begins with increasing trend upto September. It declines in November, December and remain some what stable upto May. Free carbon dioxide values also show direct correlation with alkalinity (Table 7). In December' 95 when Free carbon dioxide was only zero to 1.0 mg/l, alkalinity was also low (102 mg/l). With the increase of free carbon dioxide (0 - 50 mg/l), average alkalinity increased to 130 mg/l.

Phosphate - Phosphorus (Po^-_4): Phosphorus is extremely important inorganic constituent and occur in several forms. In the present investigations only phosphate values were estimated which is biologically available form found in the aquatic ecosystem. The concentration of phosphate in water ranged from 0.065mg/l to 0.72mg/l (Table 9). Seasonal distribution is very well attaining a peak in summer and minimum in monsoon period but it is usually low throughout the year. Main contributor of phosphorus in Pahunj reservoir are sewage effluents, surface runoff and other organic matters. Lowest value (0.065mg/l.)were trace values and indicates excessive depletion in the month of September' 95. Phosphate values shows relationship with other chemical parameter upto certain extent . Some of these are dissolve oxygen and pH..

Nitrate - Nitrogen (No_3^-): Nitrogen Nitrate usually occurs in small concentration and recorded average value was 0.3mg/l. Nitrate concentration ranged from 0.15 mg/l to 0.7mg./l, confirming sufficient availability in this reservoir. Seasonal variations are there and maximum values were recorded in the month of June' 95 (0.62mg/l.). Concentration of Nitrates varies in flow of water showing minimum values of 0.15mg/l in August' 95. A wide range of nitrate variation is the result of increased biological activities from December (0.25mg/l to June' 96 (0.7mg/l.). The main source of nitrogen compound in Pahunj reservoir is city sewage and catchment runoff. Investigation shows that Nitrate values varied with other chemical constituent having more conspicuous relationship with volume of water (Table 9).

Alkalinity :- Total alkalinity was mainly due to carbonates and bicarbonates present in the water. Carbonates, bicarbonates and some times hydroxides together with Calcium (Ca), Magnesium (Mg), Sodium (Na) and Iron (Fe) contribute for the alkalinity. Reservoir water recorded alkaline throughout the study period. pH, carbon dioxide and alkalinity exhibit interrelationship (Table 8). Alkalinity never depleted below 100 mg/l, being lowest in December' 95. Maximum values were recorded in the month of October' 95 (203 mg/l at 9.30 hrs). However, it remains somewhat stable from April to September.

B. Discussion

pH : Several workers has reported pH value for different reservoirs. Some of the notable contributions are Natrajan (1981) for Rihand (pH 7.9), Pathak et.al. (1989), Govind Sagar (pH 8.8) and Nagarjun Sagar (pH8.3). pH values (pH 8) recorded for Pahunj reservoir are within the range reported by above mentioned workers. Gaur and Khan (1994), reported higher mean values (pH 8.7) for a pond water from Aligarh and attributed it to the dominance of photosynthetic activity over respiratory activity (Khan & Khan,1985).

pH of water mainly depends on carbon dioxide cycle of water because it contributes for carbonate (co^-_3) and bicarbonate (Hco^-_3)or more preciously hydroxide (OH^-) ions in the water. In photosynthetic zone chlorophyll utilizes carbon dioxide from bicarbonate ions and leads to increase of carbonate and pH. At the same time in tropholytic zone consumption of oxygen and liberation of carbondioxide takes place reversing the former situation. But in absence of light i.e night, only tropholytic activity takes place enforcing unilateral reduction of oxygen and increase in carbondioxide. Observed seasonal and diurnal variations in pH of Pahunj reservoir are due to different rate of these reactions. It explain the higher pH values in morning and lower values in evening.

Substantial deflections of pH on either side create separate set of problem to biotic community. It may directly or through other members of biotic community harm the fishes. Jhingaran (1987) stated that major shift in pH weakens the biogenic capacity of water body. Swingle (1967 a) summarised that water with a pH range of 6.5 to 9.0 is most suitable for fish culture because it reflects the consistency in trophogenic and tropholytic activities. In the case of present studies higher gross primary productivity values confirms above statement . In the light of these results, Nath (1997) suggested primary productivity estimation based on pH values however, this methodology needs more investigation to get credibility.

Dissolved Oxygen (DO_2) : Oxygen is the most significant among all the dissolved gases in natural water. It is important both as regulator of metabolic process and as indicator of water quality. In water biologically available oxygen remain in simple solution form. Water gets oxygen mainly from atmosphere by absorption through photosynthetic activities. Respiration by living

organism and puterification of organic matter, are the major consumers in natural water. However the volume of dissolved oxygen in water at any time depends on (1) Temperature of water (2) Partial pressure of gas in the air in contact with surface water (3) Concentration of dissolved salt (Salinity).

In Pahunj reservoir concentration of dissolved oxygen varied from 1.8 mg/l to 8.9mg/l, (average 5.0mg/l). Reported dissolved oxygen values are 7.54 mg/l for Rihand (Natrajan, 1981) 8.8mg/l for Govind Sagar, 8.0mg/l for Nagarjun Sagar, 7.5 mg/l for Bhavani Sagar, 6.8mg/l Bacchara Dam and 7.54 for Aliyar (Pathak,1997). Significant deviation from mean value is common feature both seasonally and diurnally. Among the three known income sources of dissolved oxygen, pressure of gas in atmosphere and salinity don't change easily hence variations are mainly due to photosynthetic activity. As a matter of fact, during day time both production (Photosynthesis) and consumption (respiration) takes place simultaneously. Contrary to this only consumption occurs in absence of light. Thus oxygen available in water is the balance of above two processes. Minimum and Maximum dissolved oxygen can be correlated with these factors e.g. 9mg/l dissolved oxygen were recorded at 14 hrs when photosynthesis is supposed to be at the peak. Conversely minimum values are found in the morning hrs (5-6hrs) due to respiration. Seasonal changes in dissolved oxygen concentration occur due to climatic factor and decomposition of organic matter in summer (Bhowmick & singh, 1985) but in the present case no prominent shift was observed. It proves that Photosynthetic activity is the major factor in dissolved oxygen budget. Moreover observed depletion in July ' 96 (Fig - 6) may be due to decomposition of vegetation after a long period of intense heat and depletion of water volume. Both seasonal and diurnal fluctuation are in the congenial limits and indicates that it is a biologically active ecosystem because unproductive waters are usually stable (Macan, 1974). Besides this, extreme limits i.e. complete depletion and saturation conditions were never observed confirming the suitability of environment. It suggests that oxygen is not limiting factor for Pahunj reservoir water.

Free Carbon dioxide (CO_2) : The importance of free carbon dioxide for an aquatic environment derives from three factors (1) Chemically it acts as buffering agent against rapid shift in acidity -

alkalinity state (2) It regulates biological process in aquatic communities (3) It is the most versatile element which can form numerous compounds. Both lower and exceptionally higher values of free carbon dioxide are harmful to fishes (Laglar, 1982), Carbon dioxide in natural waters comes from a number of sources. The important ones are 1) Atmospheric carbon dioxide 2) Seeping ground water 3) Chemical reaction in water 4) Respiration and 5) Bacterial decomposition in tropholytic zone. In aquatic ecosystem carbon dioxide is generally found as 1) free carbon dioxide in solution and carbonic acid 2) combined carbon dioxide 3) Aggressive carbon dioxide required for maintenance of $Ca\ Co_3$ in water.

In present case free carbon dioxide ranged from 0 to 5 mg/l and maximum values were recorded in September (morning). The average for entire study period is 2.5 mg/l. Khan (1997) recorded free carbon dioxide values of Bacchara reservoir for six years i.e., 0-4.60 mg/l (1982), 0-3.05mg/l (1983), 0-3.8mg/l (1984), 0-6.73mg/l (1985), 0-6.0mg/l (1986) and 0-7.2mg/l (1987), average being 1.32mg/l. Further Khan (1997) has also reported the free carbon dioxide 0-4.3mg/l in Gulariya, 0- 3.0mg/l for Baghala, and 0-10mg /l in Aliyar reservoir respectively.

Presence of free carbon dioxide in Pahunj reservoir was more distinct in morning due to absence of photosynthesis and presence of respiration activities in the night. With the sunrise it gradually gets depleted. Presence of free carbon dioxide and low pH value indicates domination of respiration over photosynthetic activity. Increased vegetation in postmonsoon period supplements carbon dioxide in water through respiration while in summer it liberates free carbon dioxide by decomposition. Higher value of free carbon dioxide shows that amount which was produced during respiration and decomposition were not fully utilized during photosynthesis. Carbon dioxide values in Pahunj coincide with plankton peak period i.e. November and December, indicating its utilization by phytoplanktons.

Total Alkalinity : Reid (1961) described that natural water may have three different component responsible for alkalinity. These are bicarbonate hydroxide ions of calcicum (Ca), Magnesium (Mg), Sodium (Na) and Potassium (K) etc. They may occur individually or together, but each has separate set of condition and testing methodology. In Pahunj reservoir bicarbonate, free

carbon dioxide and hydroxide alkalinity was observed. Hence reported values are phenolphtheleine and methyl orange alkalinity. As the pH of Pahunj water mostly ranged from 6.8- 9.2 , it implies that carbonate, bicarbonate and free carbon dioxide is responsible for alkalinity (Jhingaran,1992). Total alkalinity in Pahunj water ranged from 100mg/l to 203mg/l (average 122.375mg/l). Alikuhni (1957) stated that productive waters usually possess more than 100mg/l alkalinity. Pathak (1997) reported lowest alkalinity for Rihand 43.8mg/l and highest for Bacchara 127.64mg/l. Average alkalinity for Indian reservoirs come around 68.8 mg/l (Khan, 1997). Pahunj shows similarity with Bacchara reservoir (137.7mg/l) which is a small water body almost of same geo-climatic conditions. Natural water bodies shows wide fluctuation of alkalinity depending upon geology, meteorology and ecology etc.. Jhingaran (1992), mentioned that, stagnant waters of a tropical place lying in low rainfall area likely to have a high total alkalinity. Seasonal variation exhibit relationship with rainfall, water quantity, plankton population and sunlight. In cloudy days when sunlight remain insufficient photosynthesis happens to be low which means high carbon dioxide and consequently less alkalinity. Pahunj reservoir receive considerable quantity of sewage from Jhansi city which supplements alkalinity and organic carbon regularly. Highest value recorded for October' 96 (136-203mg/l) may be attributed to abundance of plankton population and other vegetation which produces more carbon dioxide. Alkalinity directly affects the well being of fishes, because low values are biologically less productive than those with high values. Car Lander (1955) observed significant increase in standing crop with the increase in carbonate (CO_3^-) contents. In present case alkalinity values are moderate and place this reservoir in productive category (Sugnan and Jhingran,1990).

Phosphorus (P) as Phosphate (PO_4^-) : Ecologically phosphorus is most critical single factor in the maintenance of bio-geochemical cycle, because phosphorus is essential component of energy transfer system. Although it is required in very small quantity, but its deficiency may lead to inhibition of phytoplankton and subsequently low productivity of system. This element does not occur free in nature. Phosphorus in natural water can be categorised into inorganic phosphate phosphorus, soluble organic phosphorus and particulate organic phosphorus of seston. The

occurrence and abundance of particular type largely depends upon geochemical condition of water. Main supply of phosphorus in natural water comes from leaching of soil, rock and organic matter of all available soluble phosphate phosphorus and particulate phosphorus of sestons are relevant in natural waters and it may enter into combination with usually abundant calcium. pH usually determines the nature of compounds which usually is calcium phosphate prevails under moderate alkaline conditions. Mortimer (1942), has shown that release of phosphorus from ferric Iron - phosphorus complex is governed by oxygen. Jhingaran (1992), mentioned that natural water having a phosphorus content more than 0.2mg/l are likely to be more productive. Pathak (1997), summarised phosphate values for some reservoirs. It ranged from 0.01mg/l for Nagarjun Sagar, 0.01mg/l for Rihand and 0.144 mg/l for Bacchara reservoir. Pahunj water has cosinderable concentration of phosphate being average 0.27mg/l. Review of literature reveals that smaller reservoir possess higher phosphate contents (Jhingaran 1988, Pathak 1979, Natrajan 1985, Khan 1997). In the present case however, higher concentration may be due to regular intake of sewage cattle dung from large number of grazing animals in periphery and agriculture runoff etc.. Seasonal variation in phosphate contents commensurate with related factors . Maximum concentration occurs in summer when water level is low and decomposition as well as putrefaction get enhanced. Monsoon depletion is obvious due to high water level and greater intake by growing vegetation and fish fauna.

Nitrogen (N) as Nitrate (NO_3^-) : Nitrogen is important for synthesis and maintenance of protein, a vital building material for all living organisms. Derived from atmosphere, nitrogenous compounds in natural waters may be from outside source or from within the body of water former category include rain water, ground water and surface runoff. Endogenous compound from fixation process carried by bacteria and algae. (Reid ,1961) described two sources for the elemental nitrogen (i) atmospheric (ii) bacterial denitrification. This elemental nitrogen is inert and has very negligible role in biological cycle. The synthesis of inorganic sustance in living tissue and metabolism of protoplasm produces organic nitrogenous compound e.g. protein, urea, uric acid and metabolic waste of the total nitrogen present in living world of which 50% belongs to this category. In

addition to these two forms, nitrogen also occurs as inorganic nitrogen compound and nitrite nitrogen. Nitrate nitrogen is biologically most important form of nitrogen used in protein systhesis. It is formed by decomposition of nitrogenous substance. It occur in relatively low concentrations and world average is about 0.30mg/l bacterial nitrification is the main source for these compounds (Hutchinson ,1967).

In Pahunj reservoir it ranged from 0.15 mg/l to 0.7mg/l with an annual average of 0.32mg/ l mg/l. Pathak (1997), reported 7mg/l for Nagarjun Sagar,4 mg/l for Rihand and 0.27 mg/l for Bachhra.It means that Pahunj water contains moderate range of Nitrate nitrogen required for productivity. Banergea (1967),, has attended to correlate fish production with available nitrogen in fresh water fish pond and recorded high values (0.7mg/l) for summer months which may be due to decaying organic matter and vegetation. Seasonal trends appears to be regular and fluctuation are prominent. Ganapati (1960) pointed that unpolluted tropical water remain deficient in nitrate but receive organic load as sewage and this may be a reason for nitrogen concentration.

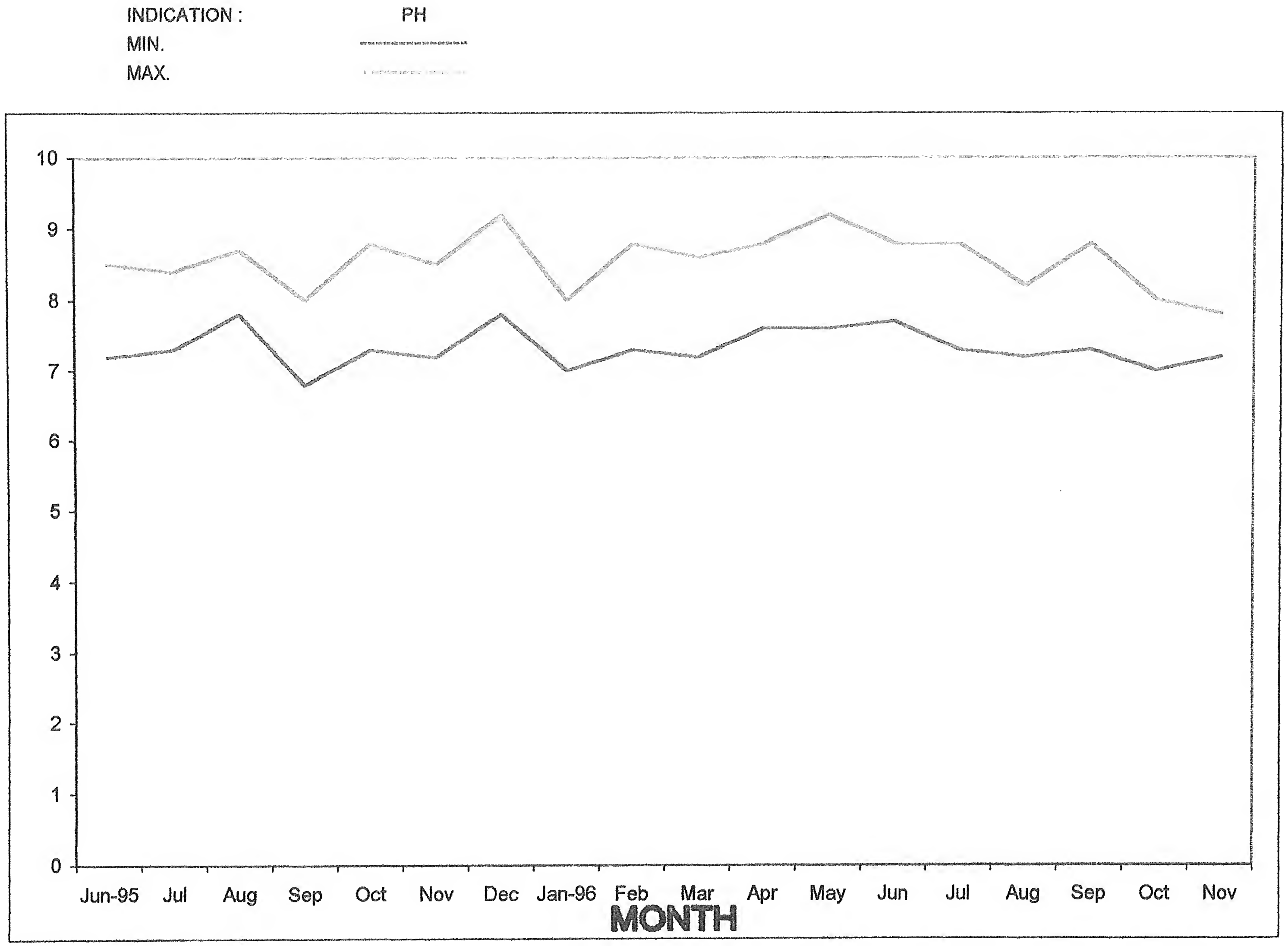


FIGURE-5 : Seasonal variation of pH in Phaunj reservoir.

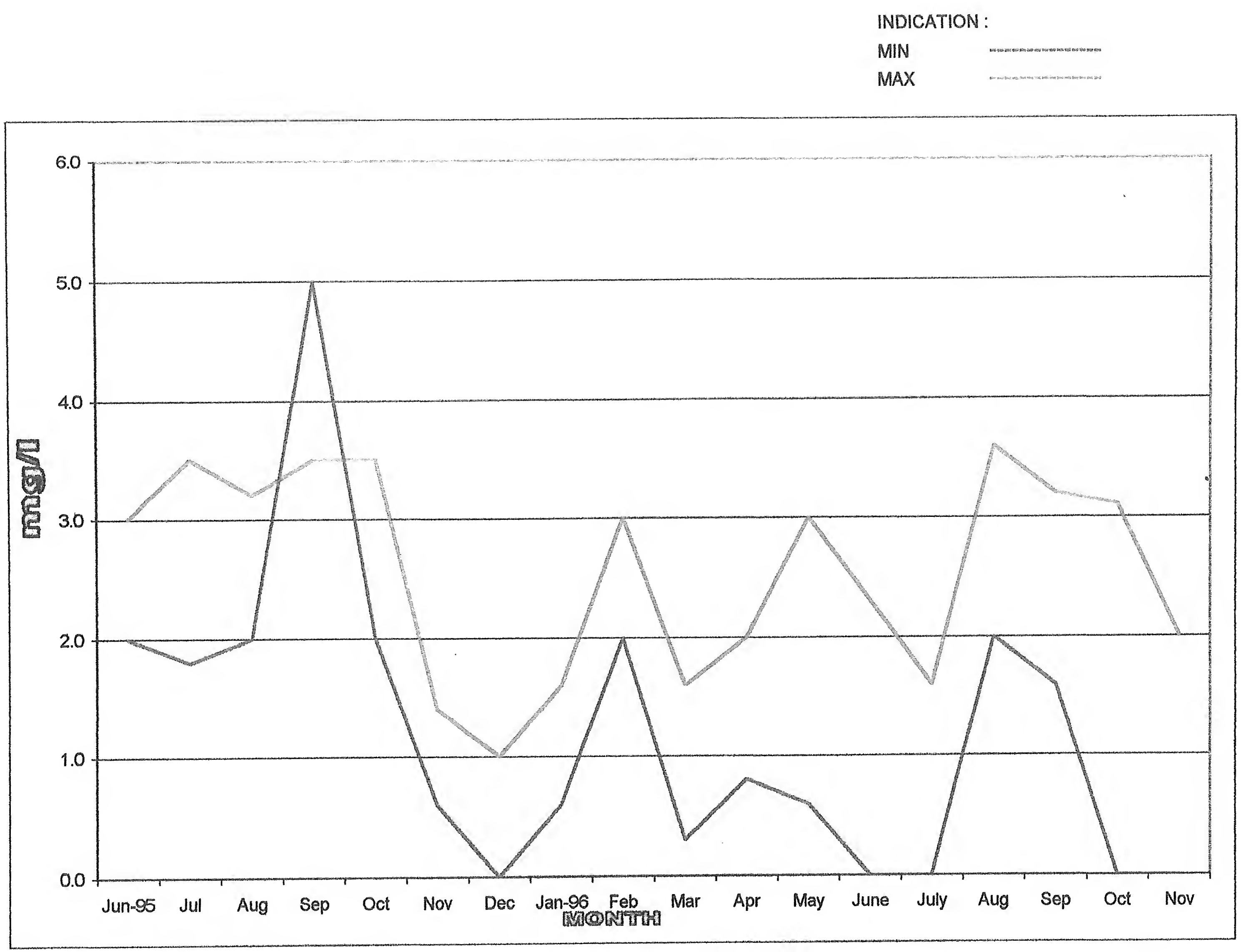


FIGURE - 6: Seasonal variation of free carbon dioxide in Pahunj Reservoir.

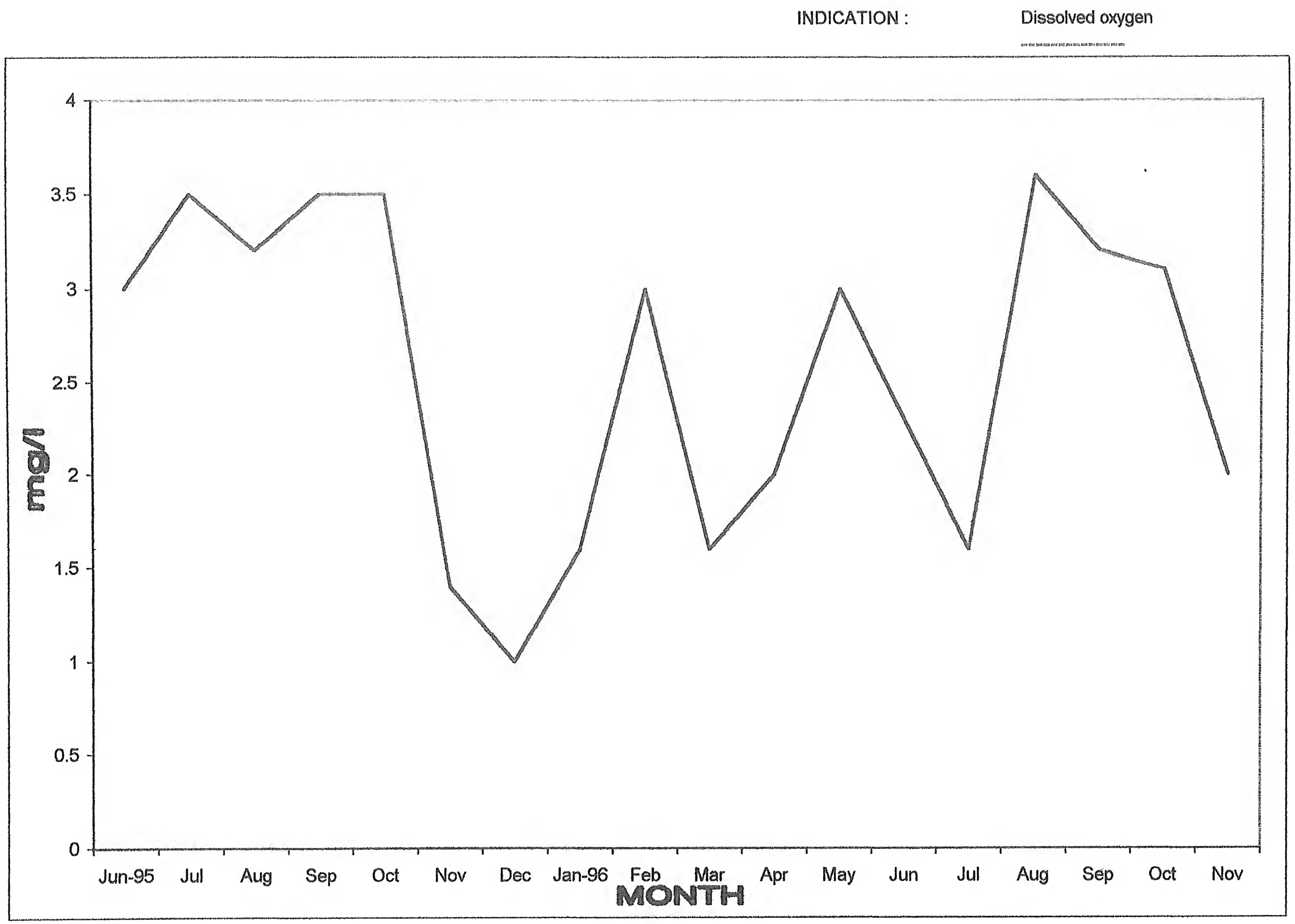


FIGURE - 7 : Seasonal variation of maximum dissolved oxygen in Pahunj reservoir.

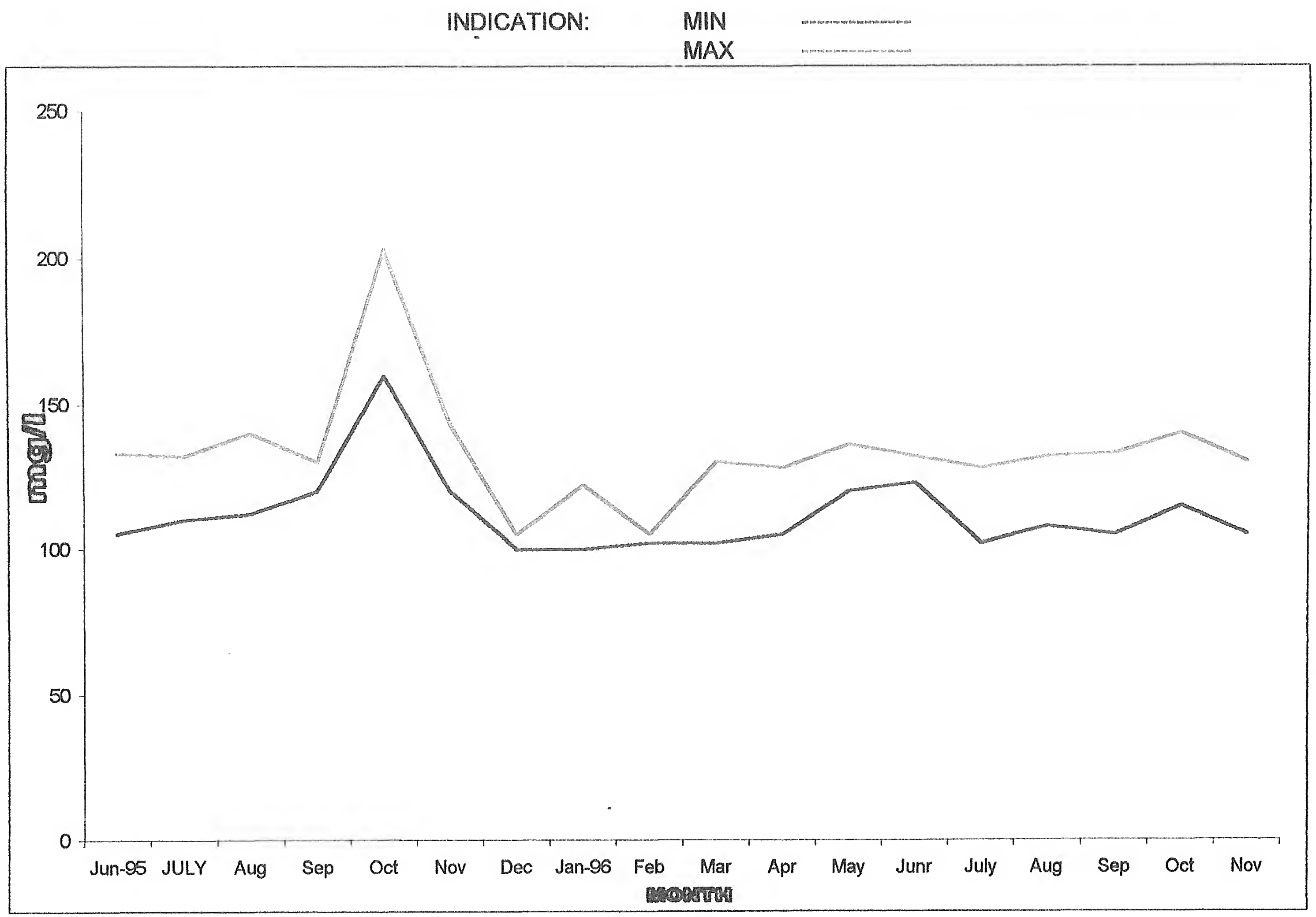
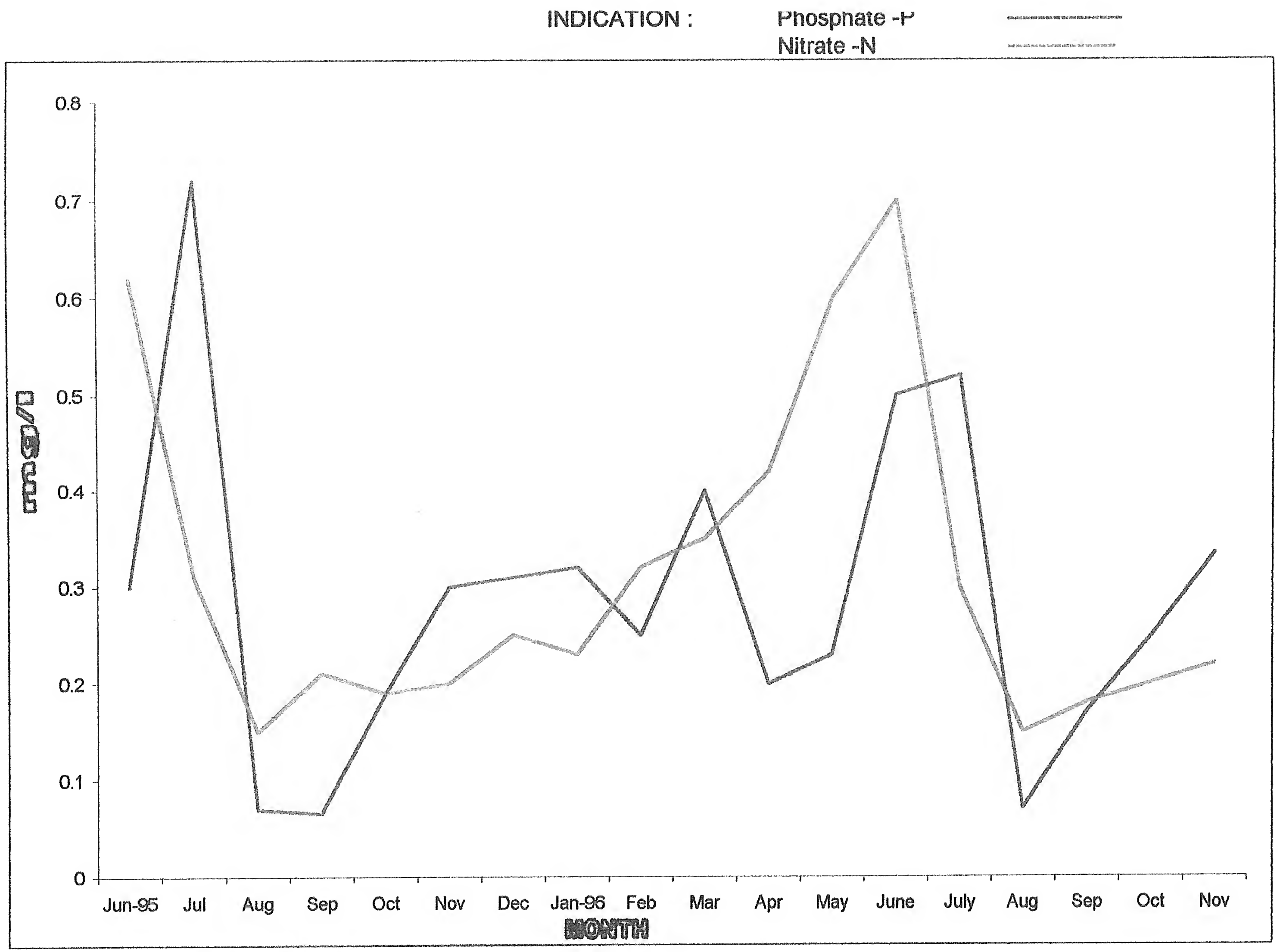


FIGURE - 8 : Diel and seasonal variation of total alkalinity in Pahunj reservoir.



FIGUER - 9 : Dieal and seasonal variation of phosphate and nitrate in Pahunj reservoir.

Chapter -5

Population Dynamics

A. Observations

B. Discussion

A. Observations

Reservoirs usually reflect the flora and fauna of parent river system. The relative abundance of each species depends on the morphometric, hydrological and ecological features of parent river ecosystem. As the Bundelkhand lies in central plateau region where rocky bottom is frequent. In the present case continuous silting has covered the entire surface of reservoir by incoming black cotton soil. In case of managed fisheries like pahunj reservoir annual stocking of fish seed and introduction of exotic fishes also bring some changes in bio-diversity.

Plankton. Plankton comprises the world of drifting or weakly swimming aquatic beings that are mostly minute in size and at the mercy of water movement. They include phytoplankton as well as zooplankton and collectively known as helioplankton.

Phytoplankton- Phytoplankton are chlorophyll bearing organism and occupies the lowest level in food chain pyramids. Since most of the reservoirs receives monsoon runoffs from catchment area the colour, transparency, nutrient level and pollution load etc. of water undergoes changes which influences the photosynthetic activity of holophytes. Phytoplankton mainly pertains to the group chlorophyceae, Bacillariophyceae, Euglenophyceae, Myxophyceae and rarely Dinophyceae. Presence of about Thirty Nine genera is recorded in pahunj reservoir. In order of abundance they can be represented as Myxophyceae > Chlorophyceae > Bacillariophyceae > Desmids > and Euglenophyceae. Individual members of each family is as follows :

family	Genera
A.Myxophyceae	1.*Microcystis*
	2.*Phormidium*
	3.*Oscillatoria*
	4.*Anabaena*
	5.*Merismopodia*
	6.*Tetrapedia*
	7.*Coelosphaerium*
	8.*Nostoc*

	9.*Spirulina*
B. Cholorophyceae	10.*Scendesmus*
	11.*Microspora*
	12.*Pediastrum*
	13.*Botryococcus*
	14.*Coelastrum*
	15.*Selenastrum*
	16.*Tetraspora*
	17.*Ulothirx*
	18.*Protococcus*
	19.*Spirogyra*
	20.*Zygnema*
	21.*Ophiocytium*
	22.*Cocconeis*
C. Bacillariophyceae	23.*Amphora*
	24.*Synedra*
	25.*Stephanodiscus*
	26.*Cyclotella*
	27.*Navicula*
	28.*Frustulio*
	29.*Nitzschia*
	30.*Melosira*
	31.*Diatoma*
	32.*Astreionella*
	33.*Stauroneis*
	34.*Gonatozygon*
D. Desimidae	35.*Docidium*

	36.Desmidium
	37.closterium
E. Euglenophyceae	*38.Euglena*
	39.Phacus

Number of phytoplankton per unit volume of water was enumerated by following Endmondsons (1957) and Needham and Needham (1963) methods.There number varied 340 /l to 1913 /l of water volume (table 11) Minimum number of 340 to 400 was recorded in September and October 1996. While maximum number was recorded during June 1995. Numerically seasonal fluctuation was very prominent (figure 10) during periods of investigation. It achieves peak during winter months of November and December and second one in May and June. This fluctuation in abundance shows a definite relationship with prevailing physico-chemical parameters (Fig 13). An inverse relationship was found in between phytoplankton number and the transparency of water. While a positive relationship exists between phytoplankton dissolved oxygen , phosphate and pH.

Zooplankton : Samples were collected from different locations for quantitative and qualitative estimation of zooplankton. Results have been expressed numerically in units of per liter water volume. All together eighteen species were identified under three main groups 1. Rotifers 2. Cladocerans and 3. copepods. Number of eggs and nauplii of each species were lumped together. The recorded species were as follows :

Group	Species
A.Rotifera	*1.Brachionus calyciflours*
	2.Brachionus bidenta
	3.Brachionus plicatilis
	4.Brachionus havanaensis
	5.Brachionus quadridentata
	6.Brachionus angularis
	7.Keratella canadensis

	8.Filinia brachiata
	9.Filinia lonigseta
	10.Testudinella Spp.
B-Cladocerons	*11.Daphnia simillis*
	12.Daphnia mangra
	13.Ceriodaphnia cornuta
	14.Diaphanosoma Spp.
	15.Moina Spp.
C-Copepods	*16.Cyclopes strenus*
	17.Cyclopes virdis
	18.Mesocyclopes Spp.

Cladocerons were found to be dominant group followed by Rotifers and Copepods. Survival of zooplankton primarily depend on dissolved oxygen while pH and temperature are secondary factors. Maximum number of Cladocerons recorded in May' 96 and minimum in June' 96. *Daphnia simillis* and *Daphnia mangra* occur in most of the months. They appear in the month of September and steadily increases upto November. Further the winter colds again causes decrease in number (table 12). *Daphnia mangra* was almost completely absent in winter, summer and monsoon seasons. It appears in February and gradually increases upto April. *Ceriodaphnia cornuta* was not seen in January and February'96. It appears in March and reaches its maximum density in May'96. Absence in winter months indicates there intolerance to low temperatures. *Diaphanosoma* Spp. were recorded in all samples except in December and January when they were scare. This species shows maxima twice a year,i.e. in November and June. During monsoon periods its number ranged 8/l to 40/l but increases upto 90/l during November. This species is also intolerant to low temperature (Table 12). *Moina affinis* was in moderate quantity and it never crosses 25/ l which was recorded in April'96. Although it remained present in all months during investigation but winter and monsoon were the lean periods. It increases with spring and set to decline after April'96. Copepods were represented by three species of cylopoids namely *cyclops strenus*, *cyclops*

viridis and *Mesocyclopes edese*. Among these cyclops virdis is most common. It shows maxima in summer months having a peak in July'96 (240/l). Winter maxima happens in November and December (136 to 95/l). *Cyclops sternus* was second dominant species. It also exhibit summer maxima and minima during winter and monsoons periods. *Cyclops virdis* is least abundant among copepods. It also shows summer maxima (June-102/l) and in rest of months it has negligible presence.

Rotifers had the widest species diversity and contribute major portion of total zooplankton biomass. The frequent species were *Branchionus calyciflours, Branchionus bidenta, Branchionus plicantilis, Branchionus havanaenisis, Branchionus quadridenta, Branchionus angularis*. Rotifer shows two peaks (April and November). Ten species of Rotifers belongs to only four genera mainly *Branchionus* >*Fillinia* > *Testudinella* > *Keratella. Branchionus calyciflours* was dominant species in Pahunj reservoir having 23.75 % of total Rotifer. It shows peak in November and December with the concentration of 112 to 99/l. The second dominant species is *Branchionus palicatilis* which represent 34.40 % of Rotifers. It remain present throughout the year with maxima in October, November and April. Same trends were followed by *Branchionus quadridentata*. *Testudinalla* Spp. was also quite common. It disappear in December but flourishes well in spring months. *Keratella canadensis* species also shows maxima in October'96 (10/l) and disappear in winter and summer both. It shows low tolerance to temperature fluctuation. *Filinia* genera had two species. Both of these disappear in winter, the density varies from 0 to 11/l.

Periphyton (Benthos) : The community of organism living on bottom of a water body is called benthos. Periphyton and associated tiny animals form more or less a slimy coating on bottom materials, on debris and on plants. Periphyton of Pahunj reservoir clump into three family these are as follows :

Family	species
A.Myxophyceae	1.*Phormidium* Spp.
	2.*Aphanocapsa* Spp.

	3.*Anabaena* Spp.
	4.*Oscillatoria* Spp.
	5.*Merismopedia* Spp.
B.Cholorophyceae	6.*Microspora* Spp.
	7.*Oedogonium* Spp.
	8.*Cladophora* Spp.
C. Bacillariophyceae	9.*Pinnularia* Spp.
	10.*Gyrosigma Spp.*
	11.*Cymbella* Spp.
	12.*Synedra* Spp.
	13.*Surinella* Spp.

In order of abundance they may be represented as myxophyceae> Bacillariophyceae >Chlorophyaceae. Volume of periphytons along with the number of each species were recorded on per square centimeter of solid objects. The present water body is devoid of trees, wooden logs and only stone boulders are found. Volume of periphytons varies between 0.1ml /cm^2 to 1.0ml/cm^2 while number in corresponding samples counts 95/cm^2 to 1610/cm^2 respectively. The average being 450/0.3ml/l for entire study period (Table 14). This group was completely absent during monsoon period. Different species began to appear from November onwards and last till the inflow of rain water. Maximum growth takes place in moderate temperature range available during November, December and March - April. Maxima goes upto 820/cm^2. Myxophyceae, a dominant group, constitute about 31.41 to 58.20 %. During maxima period their number touches 289/cm^2 in December. Second group Bacillariophyceae oscillate between 33 to 49.85% and like Myxophyceae this group also appears in November. Maximum number attained by this group is about 363/cm^2 in December. Chlorophyceae was least abundant group in Pahunj reservoir. This group follow same pattern as other preceding two groups. In November they were only 86/cm^2 while in summer maxima (April) their count was 503/cm^2 (Table 13).

Macro vegetation: Macro vegetation includes vascular plants which are characterised by the possession of conducting tissue for transport of material through plant body. Aqautic ecosystem usually support a limited number of vascular plants. Available species may be summarised under following categories :

Category	Species
A.Floating	*1.Lemna minor*
	2.Wolffia arrhiza
	3.Pistia Spp.
	4.Salvania cucullata
B-Emergent	*5.Potamogeton* Spp.
	6.Myriophylum Spp.
C-Marginal	*7.Ipomoea aquatica*
	8.Cyperus Spp.
D-Submerged	*9.Ceratophylum* Spp.
	10.Hydrilla verticelata
	11. Vallisneria Spp.
	12.Ottelia Spp.
	13.Dismoides Spp.
	14.Chara zeylanica

Floating species *Lemna minor, Wolffia arrhiza, Salvania* Spp. start to growth from October and make a scum or mat in shore region. These scums of 10 to 30m wide area never exceed to deeper region of reservoir. Individual numbers vary from 3000 to 3800/m^2. They begin to deplete from April onwards. *Pistia* Spp. appeared in July' 95 as it came along with the flood water from upper reaches of river. However , finally it got settled only in shallow areas. During the present study there was a remarkable increase in the *Pistia* Spp. infestation. Emergent weeds represent only *Potamogeton* Spp. and *Myriophylum* Spp. They were in small number and disappear in monsoon period. Marginal plants such as Ipomea sp and cyperus spp. are also observed in post

monsoon period. They die as water recedes from shallow region of reservoir. Their number varies from 10 to 12 plants/m^2. Submerged weeds are most abundant among all plant communities and often occupy entire water body except deeper regions making them quite important from fisheries point of view. *Ceratophylum* Spp. and *Hydrilla* Spp. are the most abudant as their number varies from 700 to 1000plant/ m^2 water area. This density becomes less in monsoon period. *Chara* Spp. is another submerged plant which was present in considerable number in entire reservoir, while *Vallisneria* Spp. occurs only in shallow region.

Fish Fauna : A comprehensive random sampling was conducted to enlist the existing fish species in Pahunj reservoir. All type of locally available nets for example Cast net, Gill net, Drag net, Scoop net, Pursein net and Hookline were employed at different locations to get a wide range of samples during commercial fishing. Compilation of annual occurrence exhibited the presence of 37genera species belonging 22 genera and representing 12 families. Cyprinidae represent maximum 7 genera including those which are annually stocked. Bagaridae and ophiocephalidae contributes 4 species each. Species wise representation of each family is as follows:

Family	Species
I.Notopteridae	1.0*Notopterus notopterus* (Pallas)
II. Cyprinidae	2.*Oxygastor bacaila* (Hamilton)
	3.*Osteobrama cotio* (Hamilton)
	4.*Rasbora daniconius* (Hamilton)
	5.*Puntius sarana* (Hamilton)
	6.*Puntius sophore* (Hamilton)
	7.*Puntius ticto* (Hamilton)
	8.*Puntius titus* (Hamilton)
	9.*Puntius phutunio* (Hamilton)
	10.*Catla catla* (Hamilton)
	11.*Cirrhinus mrigala* (Hamilton)
	12.*Cirrhinus reba* (Hamilton)

	13.*Labeo rohita* (Hamilton)
	14.*Labeo calbasu* (Hamilton)
	15.*Labeo gonius* (Hamilton)
III. Bagridae	16.*Mystus aor* (Hamilton)
	17.*Mystus seenghala* (Hamilton)
	18.*Mystus cavasius* (Hamilton)
	19.*Mystus vittatus* (Bloch)
IV. Siluridae	20.*Ompok bimaculatus* (Bloch)
	21.*Ompok pabda* (Hamilton)
	22.*Wallago attu* (Bloch & Schneider)
V. Saccobranchidae	23.*Heteropneusteus fossilis* (Bloch)
	24.*Clarias batrachus* (Lin.)
VI.Belonidae	25.*Xenentodon cancila* (Hamilton)
VII.Ophiocephaledae	26.*Channa gachua* (Hamilton)
	27.*Channa marulius* (Hamilton)
	28.*Channa punctatus* (Bloch)
	29.*Channa striatus* (Bloch)
VIII.Centropomidae	30.*Chanda nama* (Hamilton)
	31.*Chanda ranga* (Hamilton)
IX. Nandidae	32.*Nandus nandus* (Hamilton)
X. Anabantide	33.*Anabas testudineus* (Bloch)
	34.*Trichogaster fasciatus* (Bloch & Scheneider)
XI. Gobiidae	35.*Glassogobius giuris* (Hamilton)
XII. Mestacembelidae	36.*Mastacembelus armatus* (Lacepedo)
	37.*Macrognathus aculeatus* (Bloch)

Relative abundance of fishes show considerable variations. To get an idea about regional and seasonal fluctuations, sampling was done in the respective months of four seasons i.e. June,

September, January and March (table 15). Commercial fishing during winter is mainly by Gill nets when Indian major carps dominates in number. But after the decrease of water level other nets with better efficiency were employed and this resulted in wide spectrum of species. In case of weed fishes both seasonal and regional fluctuation is noticed. *Xenentodon cancila* and *Chanda* Spp. are common only in winter while cyprinids are frequent in summer.

B.Discussion

Animals and plants are important contributor of the environment and successful establishment of a species in an ecosystem depends on its tolerance of physico -chemical variables , its relation with other organisms and its behaviour which is more important during reproduction. Macan (1974) and Reid (1961) summarised that successful development and maintenance of a population depends on harmonious ecological balance between environmental conditions and tolerance of the organism to variation in one or more of these conditions. This idea suggests that either one or the other factor can limit the population. A factor that exerts influence upon a population through its compatibility is said to be a limiting factor.It may be a physical ,chemical or biological feature. Interspecific relationship involves broad spectrum of co-action, tolerance and competition among plants to plants, plants to animals or animals to animals. Intraspecific competition for food , space and breeding is equally important. Each reservoir or to say river has its own distinct fauna .As discussed earlier each species is generally confined with in a certain range of physico-chemical and biological parameters. Thus some species flourish in the congenial and some remain at low level. Fish productivity is related to this fact up to certain extent. Preserevance of biodiversity and increase in productivity work at cross purpose (Macan ,1974) .Stocking of Indian major carps is an important strategy to enhance productivity .Roughly about 0.2 million fingerlings are stocked annually in Pahunj reservoir. This administered number of three Indian major carps and exotic carps i.e.. Grass carp and common carp changes the level of competition in present ecosystem.

Studies on the ecology of phytoplankton of any water body is very helpful to know its general economy and to understand the basic nature of the reservoir. All waters are known to be characterised by quantitative and qualitative fluctuatation in the phytoplankton population .The pattern of seasonal fluctuations in air and water temperature largely agrees with the changes in solar radiation. Maximum densities of phytoplankton were observed during pre winter and post winter period when temperature was suitable for their growth and reproduction. (Table 11and Figure 10). Seasonal fluctuation in temperature and turbidity values were noted in the reservoir

(Table 2).The occurrence of seasonal qualitative and quantitative fluctuations in plankton population apparently disappear at specified periods and reappear during others. Such temporary disappearances are due to the fact that the species concern either become too scare or occurs as spores, resting eggs etc. which are not easily detectable (Hutchnison,1967) .It was observed during present investigation that some plankton which are found to be absent in some samples reappear after the condition become favourable (table). Singhal et. al. (1986) observed direct relationship between pH and phyoplankton but contrary to these findings the present studies showed a reverse relationship (Fig 10). Haque et. al. (1989) also reported reverse relationship from a tropical pond. Nitrogen and Phosphorus, the two important nutrients, show positive relationship . Phyoplankton population increases with the increase in concentration or availability of these nutrients. Dilution of water due to monsoon inflow causes depletion in phyoplankton density also. The two recorded pulse of phyoplankton during pre and post winter seasons coincides with the greater availability of nutrients.

Seasonal variation of each group and individual species were also studied. Relative percentage of Myxophyceae does not change and remain abundant throughout the year. It varies from 40-50% of total phytoplankton population. *Coelosphaerium* was most dominant genus followed by *Microcystes* and *Merismopadia*. Chlorophyecae constitute about 12.2 to 16.91% and maintain its relative contribution quite stable. Various genera under this group exhibit seasonal variations. Dominant genera were *Sendesmus*, *Tetraspora* and *Protococcus*. *Scendesmus* is known to be most pollution tolerant and may thrive very well in polluted waters (Palmer,1969). It prefer high Temperatures and exhibits only one maxima in summer (Table 2). *Tetraspora* is another dominant group which never disappears from Pahunj water. *Pediastrum* disappear in July but regains abundance in winter. Diatoms generally prefer low temperatures hence December is the most favourable period. Commonest genera among diatoms were *Synedra* and *Cyclotella*, Diatoms were almost negligible in monsoon period. Among Desmids *Closterium* contributed mainly. Monsoon is the lean period for this group. The other genera *Docidium* was absent in spring and winter, it florishes in summer only. Euglenophyceae have only two genera , these are

Euglena and *Phacus*. Their percentage varies from 10.4 to 21.19%. *Phacus* remain dominant through out year. Euglenophytes possesses better tolerance for organic pollution hence palmer (1969) recommended their use as indicator of pollution. In the present case their abundance may be attributed to sewage load of the reservoir.

Chakarvorty (1997) summarized that zooplanktons generally contribute about 15-30% of plankton and inspite of the fact that zooplankton feeds mainly on Phyoplankton, the later is not the sole limiting factor for their abundance. The growth of zooplankton always legs behind the Phyoplankton. This trend is also evident in present water body except during March and April when zooplankton takes over the Phyoplankton population .It may be due to excessive grazing of Phytoplankton by Zooplankton in otherwise suitable conditions. Fluctuation in plankton population is an established fact and several workers had reported changes in the density (George, 1962, Patil,1976 and Khan,1990). Hazelwood and Parker (1961) and Hutchinson (1967) had pin pointed several factors responsible for fluctuation of zooplankton population. Prasad (1956) opined that higher the density of Phyoplankton higher the number of zooplankton. He further explained that zooplankton number increases with Phyoplankton because of their basic dependence over later. Anderson (1987) and Khan and Siddique (1970) reported positive relationship between these two parameters. Similar results were obtained in present study. Geoge et. al. (1967) emphasized that temperature is the single most critical environmental factor controlling the reproduction of zooplankton. Each species has its own tolerance limits towards temperature. It implies that temperature is congenial for those species which are available in Pahunj reservoir. Periphytons are quite important in the productivity of an aquatic ecosystem as they occur in appreciable number in particular situation and have been found to form food of some fishes. The nature of substrate determines the composition of community up to certain extent. Besides chemical characteristics of water, water current, speed and fluctuation in water levels are decisive factors in the maintenance and development of periphytons. Table 14 shows absence of periphyton in monsoon period because the scouring effect prevent extensive colonization of bottom fauna. In addition to this silt deposition further inhibits community development .Complete absence of all

periphyton species in monsoon is the result of this phenomenon in Pahunj reservoir as it receive inflow only during monsoon period except sewage. Temperature seems to have definite correlation with the population density upto certain level . Mandal and Moitra (1975) observed peak of benthos during winter and early summer, moderate temperature range 8^0 C to 32^0 C seems to be most desirable. The chemical characteristics of the environment, operating under the principle of limiting factor acts upon the biotic structure of Aufvuch, especially when the various members of the community exhibit different reactions to dissolved substance in water (Reid,1961). Dissolved oxygen shows positive relationship. Available dissolved oxygen was seems to be sufficient to support the life activities of other organism as they are available in good quantity (fig 16). Highly alkaline waters support only a limited variety of living organism as they cannot tolerate high pH and salt concentration (Goldman and Horne,1983). Jhingran (1992) mentioned that pH of soil also influences transformation of soluble phosphorus and controls its adoption and release at soil water interface. Mean values of phosphorus varied from to 0.065 mg/l to 0.7mg/l (table 9). Higher values might be associated with the dominance of organic matter and less depth of reservoir. Nitrate and phosphate were low in monsoon and the same is the lean period for periphyton. It is evident from above investigation that maxima occur only when related factors are most suitable. Similar observation were made by Barbhuyan and Khan(1994).

Abundance of macro vegetation exhibits relationship with the water current, water level, climatic condition and availability of nutrients. Density of these plants begin to appear with settling of water in post monsoon period when temperature turns to be suitable i. e. below 30^0 c. Maximum density occurs in October, November , February and March. After the month of march sudden rise of temperature in Bundelkhand region discourages the growth of these plants. Similar is the case with nutrients. Major nutrients begin to release in October and November after the settlement of silt and organic material which encourages plants to grow. Higher population of macro vegetation coincides with planknton peaks which represents the periods of eutrophication of the reservoir. It is worth to be mentioned here that under the current management practices reservoir receives a sizable number of grass carp seed (*Ctenopherangodon idella*). This is an

ideal herbivorous fish and voraciously devours *Hydrilla* Spp., *Potamogeton*, *Vallisnaria* and *Myriophylum* . Alikuhni and Sukumaran (1964) proved their efficiency for the control of aquatic weeds.

Zoological survey of India (1991) has published that about 4000 species of fishes are found in Indian water. Gunther (1880) found 26 families in India. Day (1885) reported 87 genera in Indian fresh waters. In the present case out of these only 37 species belonging to 22 genera representing 12 families were present. Pahunj is a seasonal rivulet of Yamuna river system and the other rivers of this region are Betwa and Dhasan. But the fish fauna of these rivers is considrably different from Pahunj. This difference may be due to different geological conditions because Betwa and Dhasan are large rivers and flow of monsoon water is quite fast which erodes the silt leaving the naked rocks on the substratum . On the other hand Pahunj is a small rivulet and most of the reservoir bed is covered by clayey silt. In reservoirs of Betwa and Dhasan some of the well known local species are frequent. These are *Gadusia chapra, G. godanahiai, Rita rita, Silonia silondia, Rhinomugil corsula, Bagarius bagarius, Eutropiichthys vacha, Tor tor, Notopterus chitala* and loaches . All these species probably do not exist in Pahunj. Contrary to these species *Heteropneustes fossilis, Clarias batrachus, Trichogaster fasciatus* , *Xenentodon cancila* and *Labeo gonius* are more abundant in Pahunj. This may be attributed to muddy bottom of Pahunj and comparatively appropriate exploitation practices. From seasonal fluctuation point of view water movement, dissolve oxygen and desiccation of reservoir are important factors. Usually Indian major carps are the versatile and *Chanda spp.* were present in the upper column of deeper region of reservoir while minor carps remain in shore areas. Former two species were also abundant in winter when dissolve oxygen level was higher while the latter is common in summer when vegetation grow more. *Palaemon* species is also remain in shore areas. *Labeo gonius* is another fish which is distinctly more abudant in Pahunj.

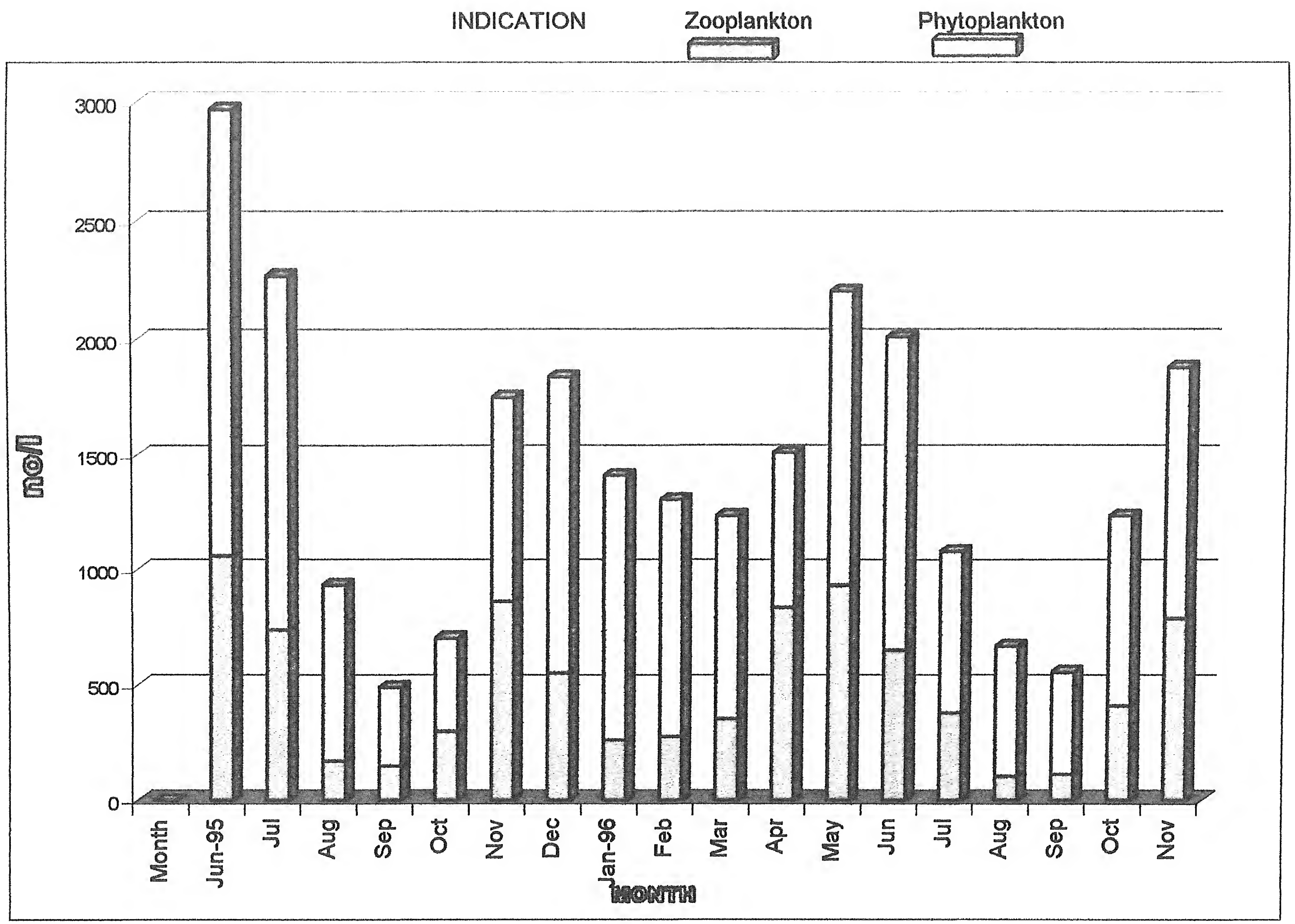


FIGURE - 10 : Monthly fluctuation of zooplankton and phytoplankton.

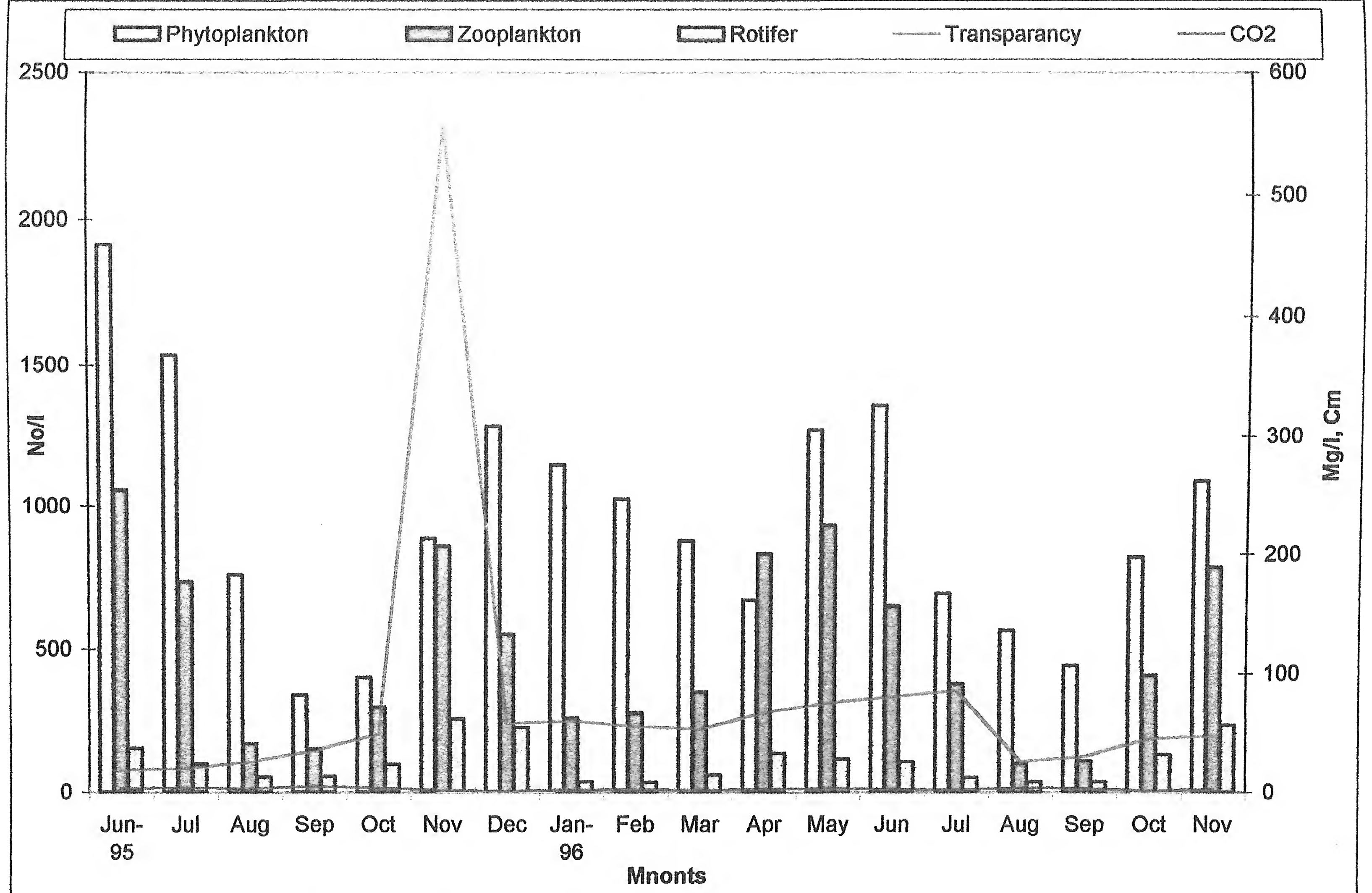


Figure-11 : Monthly fluctuation of zooplankton, phytoplankton and rotifers along with some physico-chemical parameters.

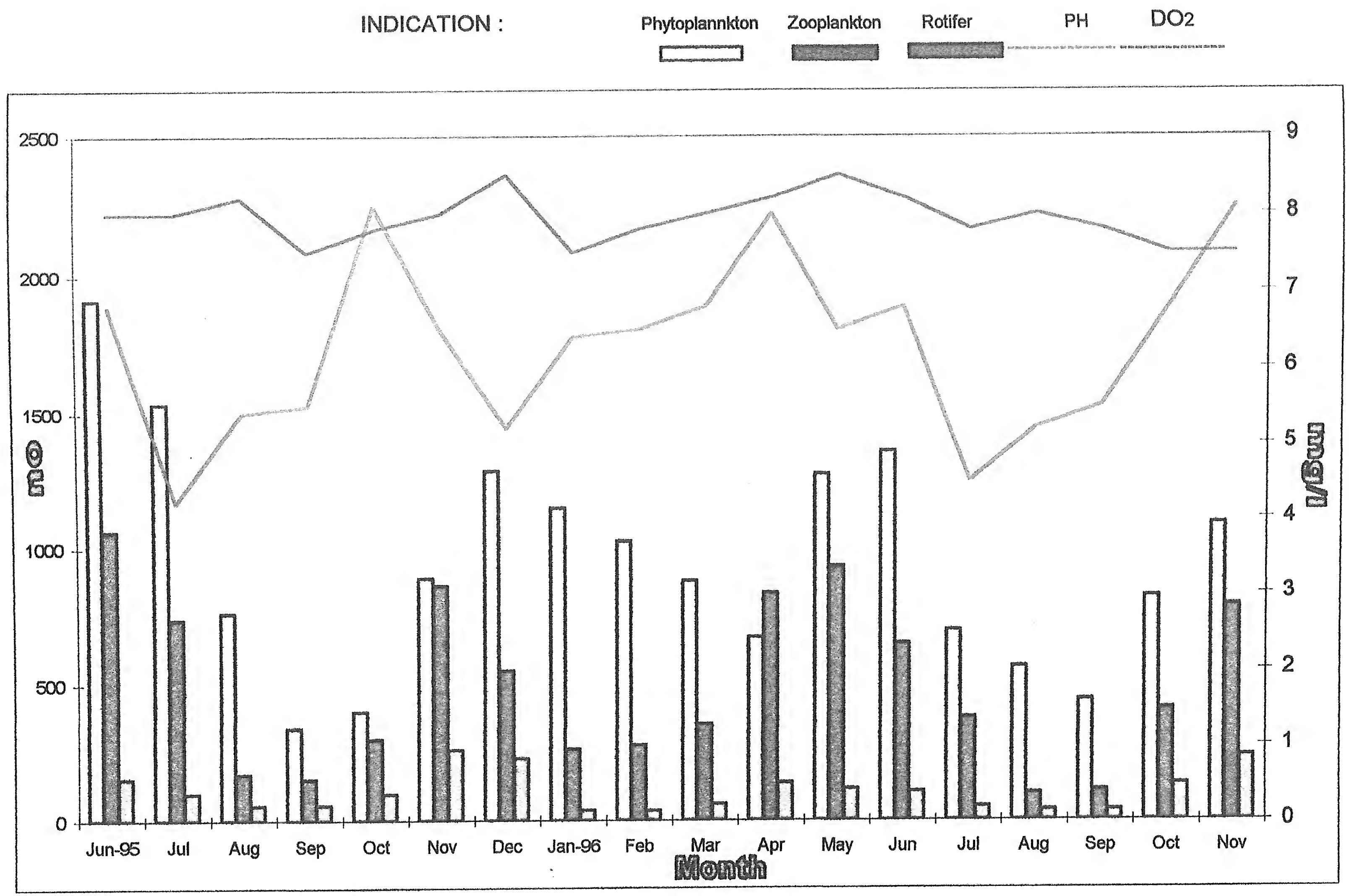


FIGURE- 12 : Monthly fluctuation of zooplankton and phytoplankton along with pH and DO2

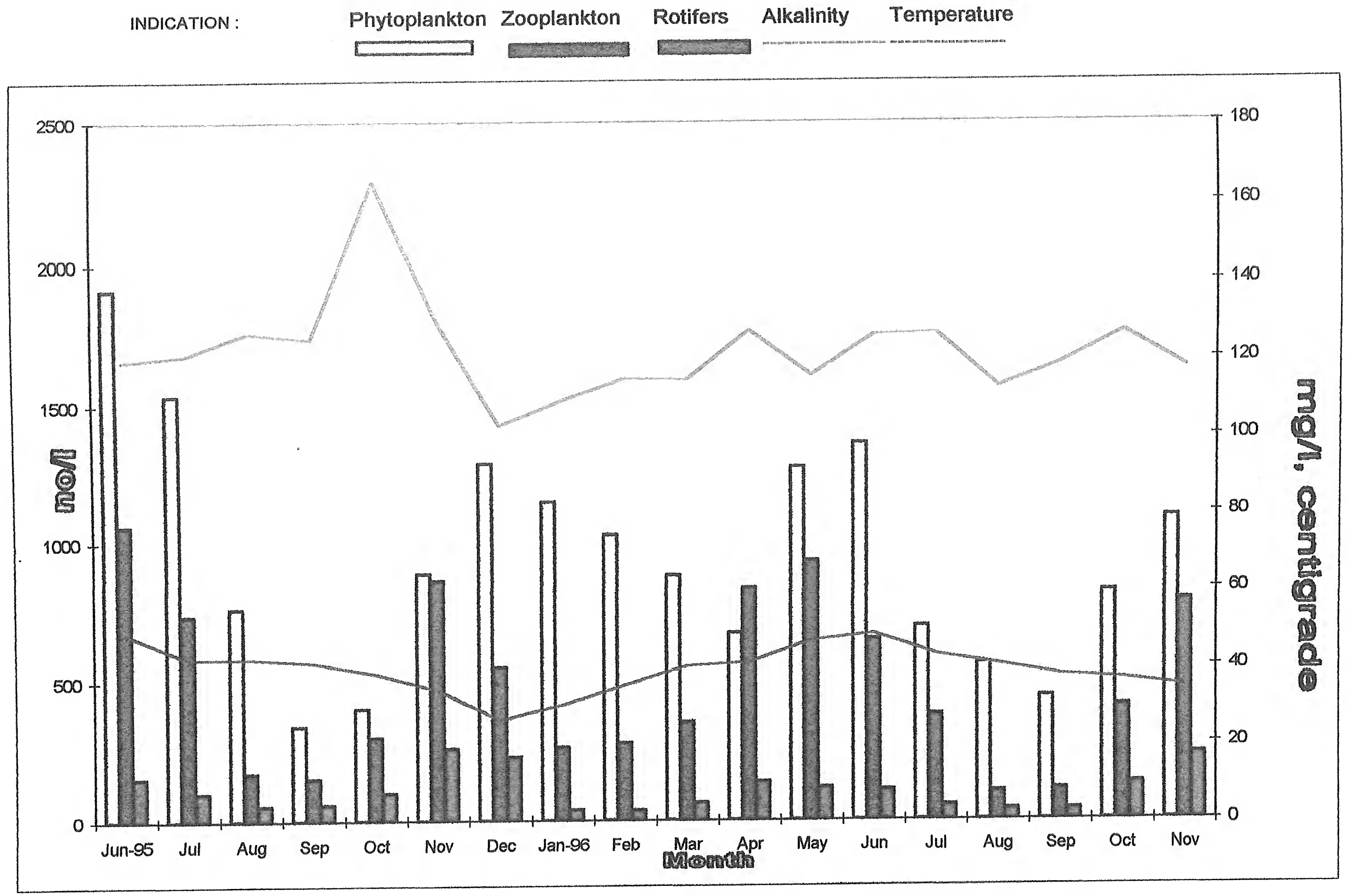


FIGURE-13 : Monthly fluctation of phytoplankton, zooplankton and rotifers along with temperature and alkalinity.

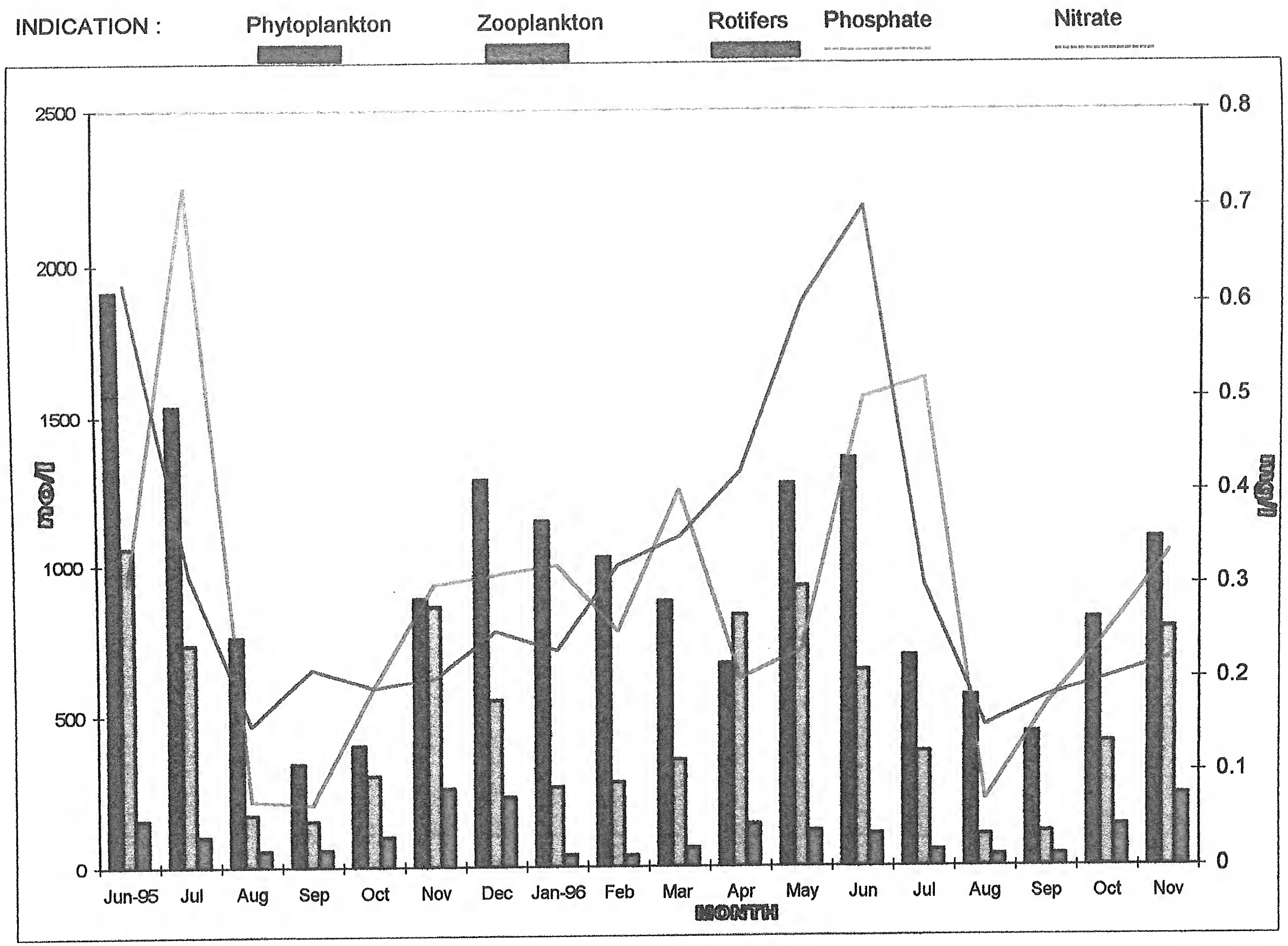


FIGURE- 14 : Monthly fluctuation of Phytoplankton, Zooplankton and Rotifers along with Phosphate and Nitrate.

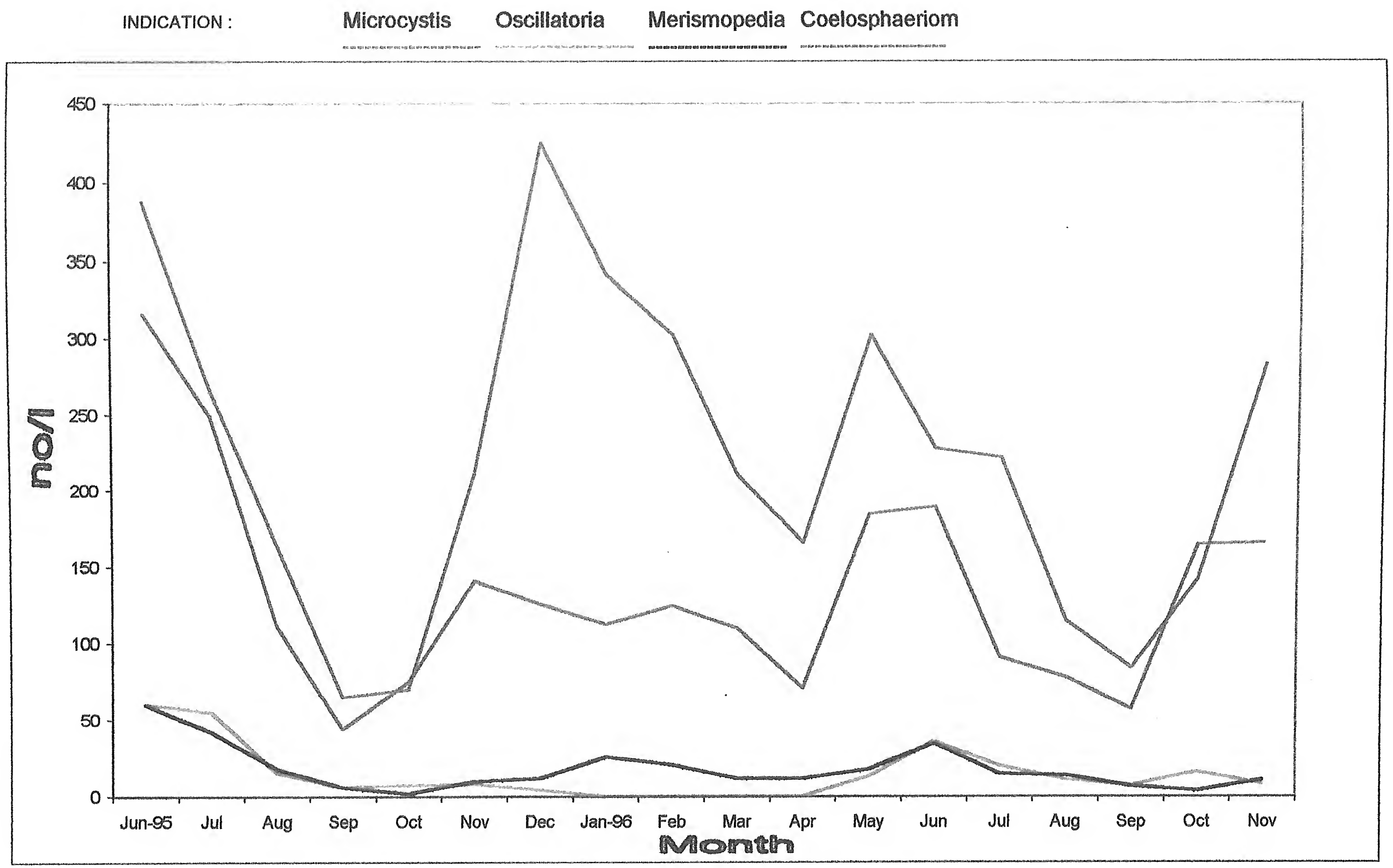


FIGURE-15 : Seasonal fluctuation in dominant genera of family Myxophyceae.

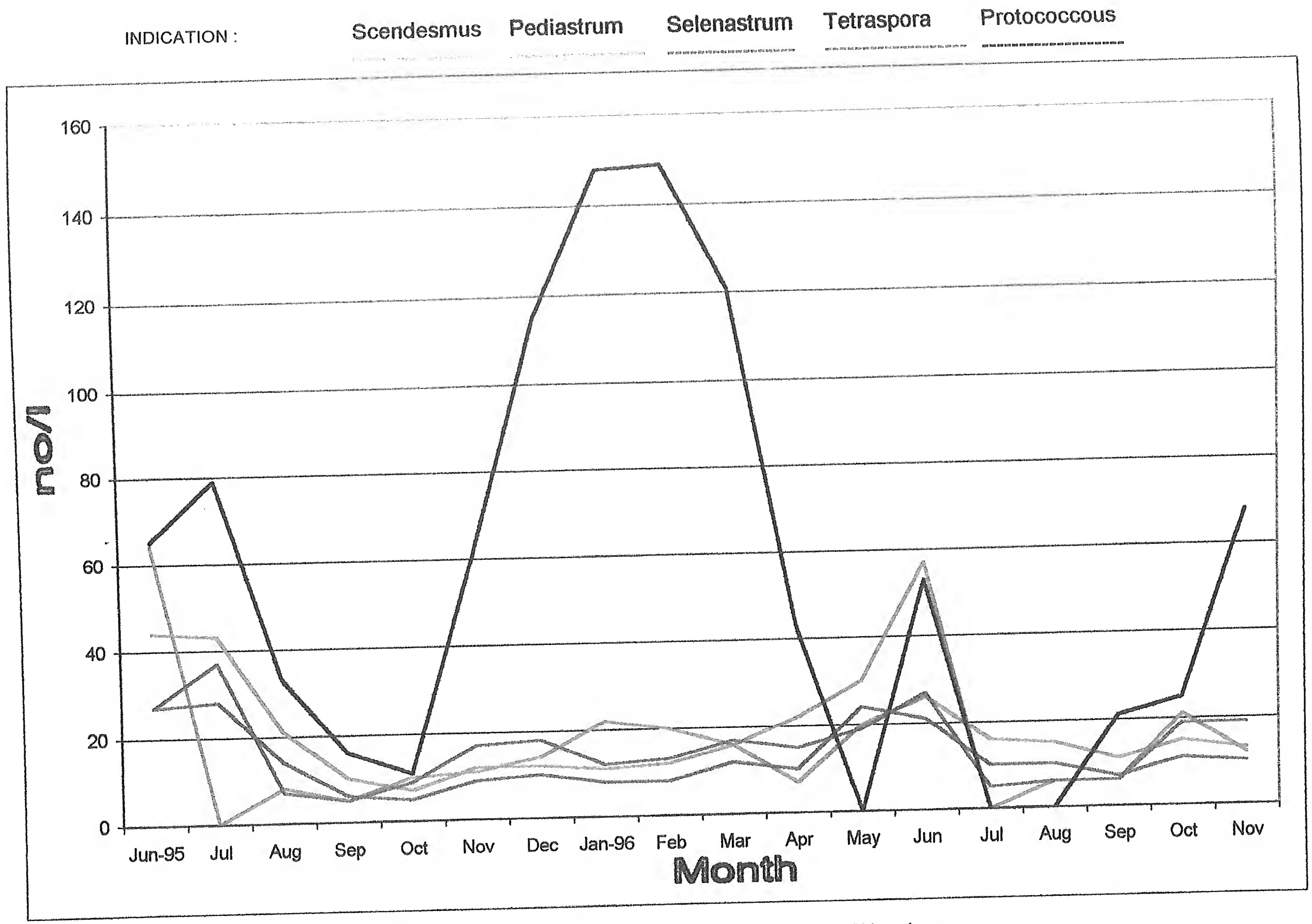
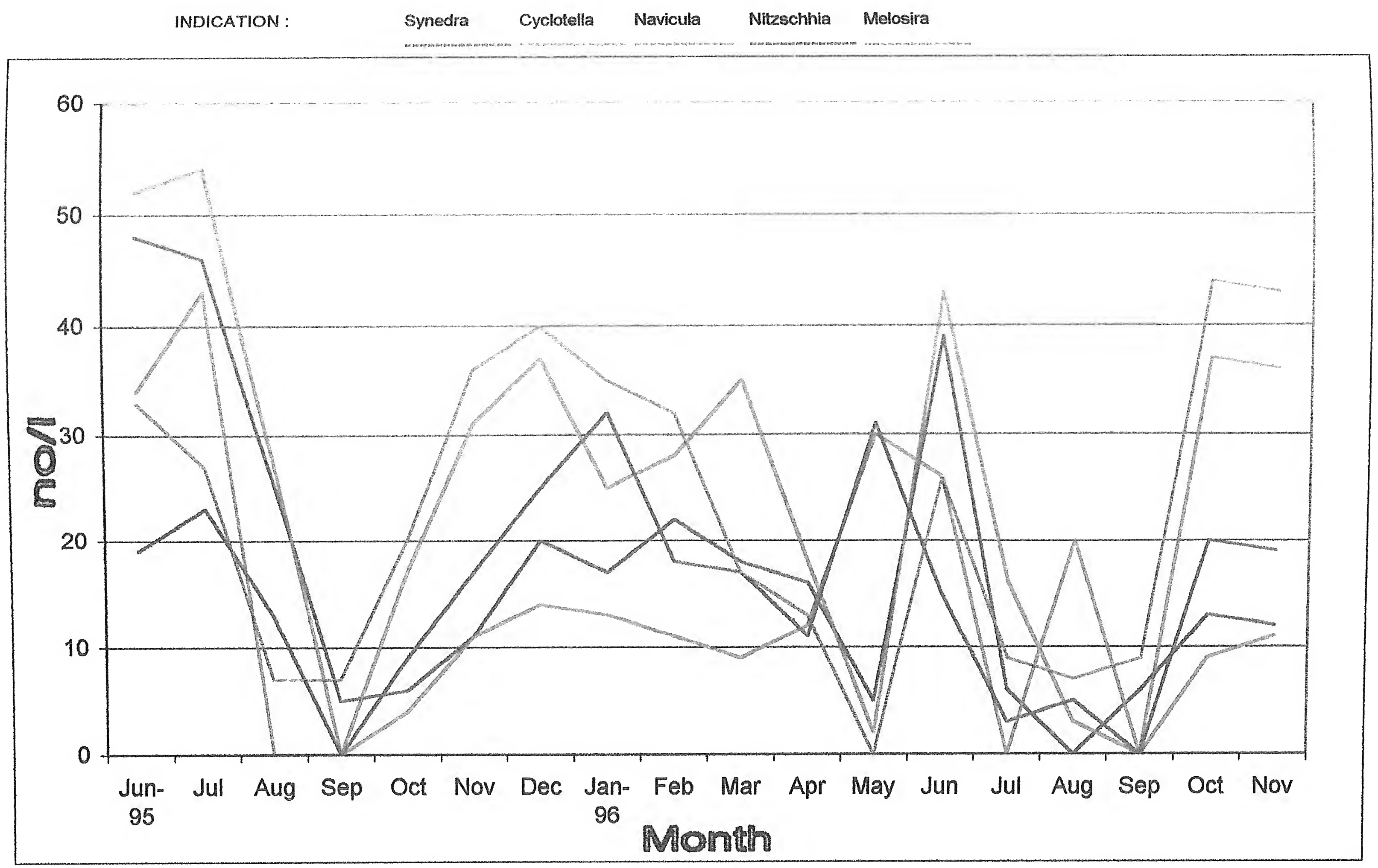


FIGURE -16 : Seasional variation in dominant genera of family Chlorophyceae.



FIGUER -17 : Sesonal variation in dominant genera of family Bacillariophyceae

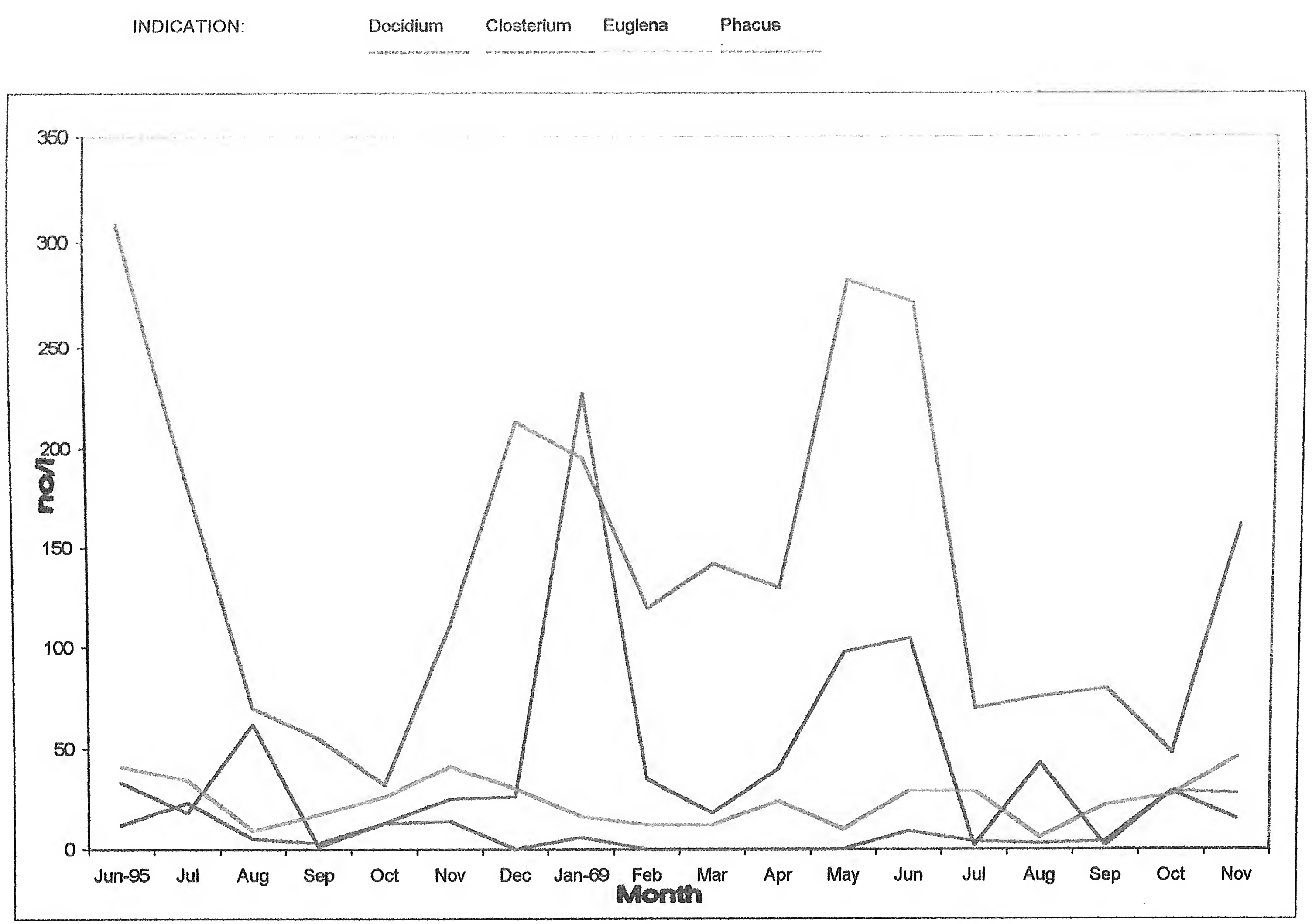


FIGURE-18 : Seasonal fluctuation in dominant genera of family Desmidae and Euglenophyceae

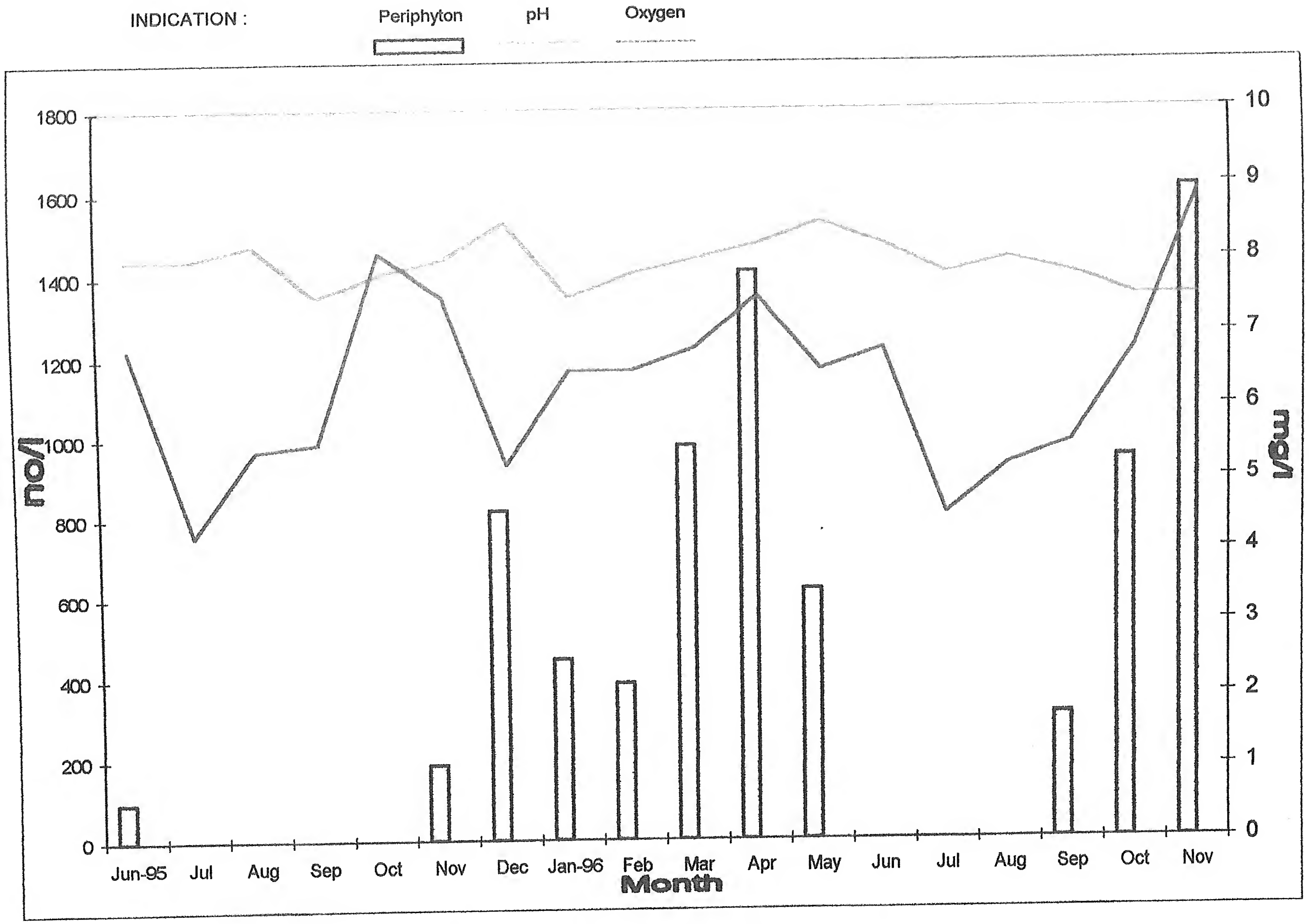


FIGURE-19 : Seasonal variation of Periphyton along with pH and Oxygen

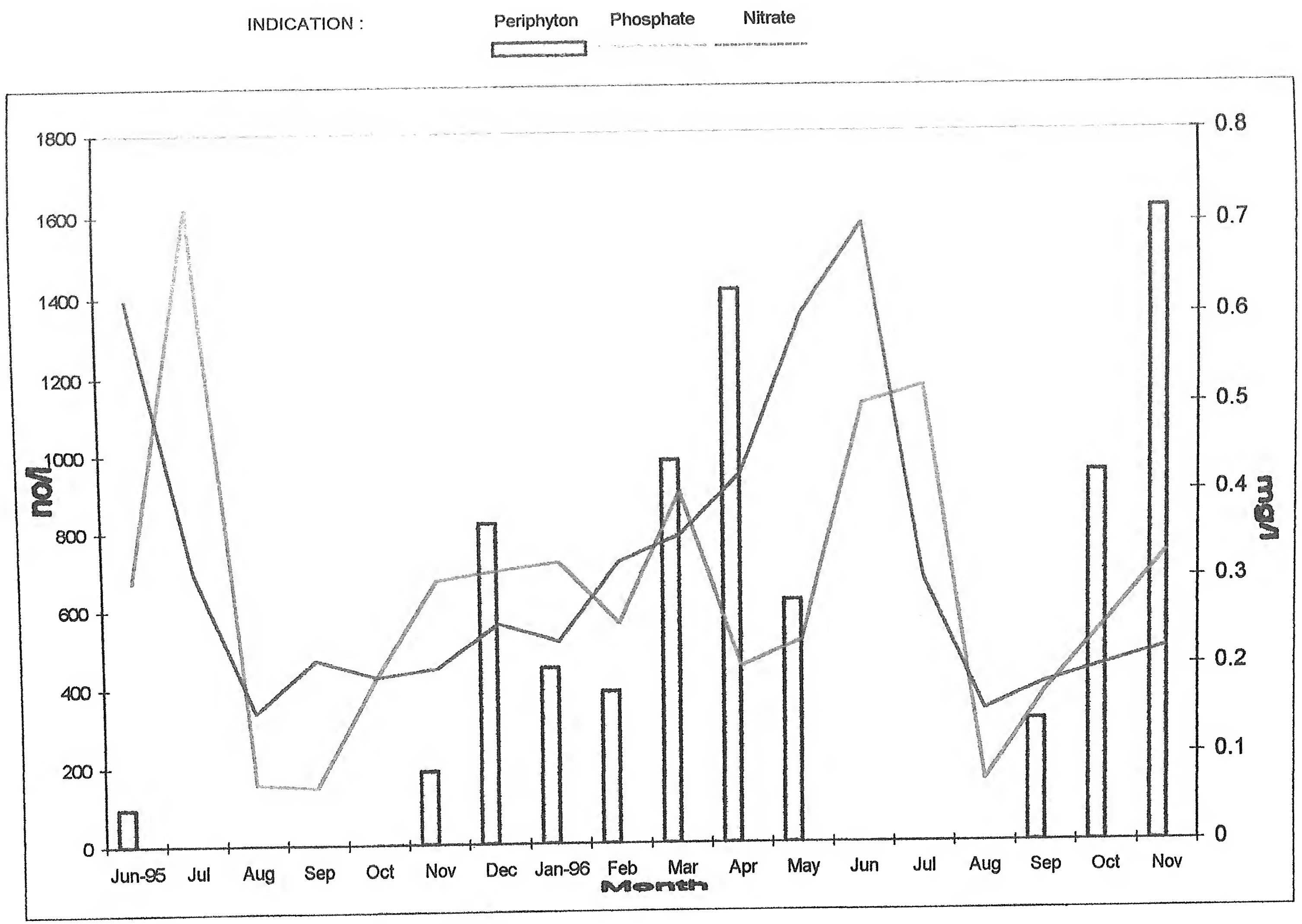


FIGURE-20 : Monthly fluctuation of Periphyton along with phosphate and nitrate.

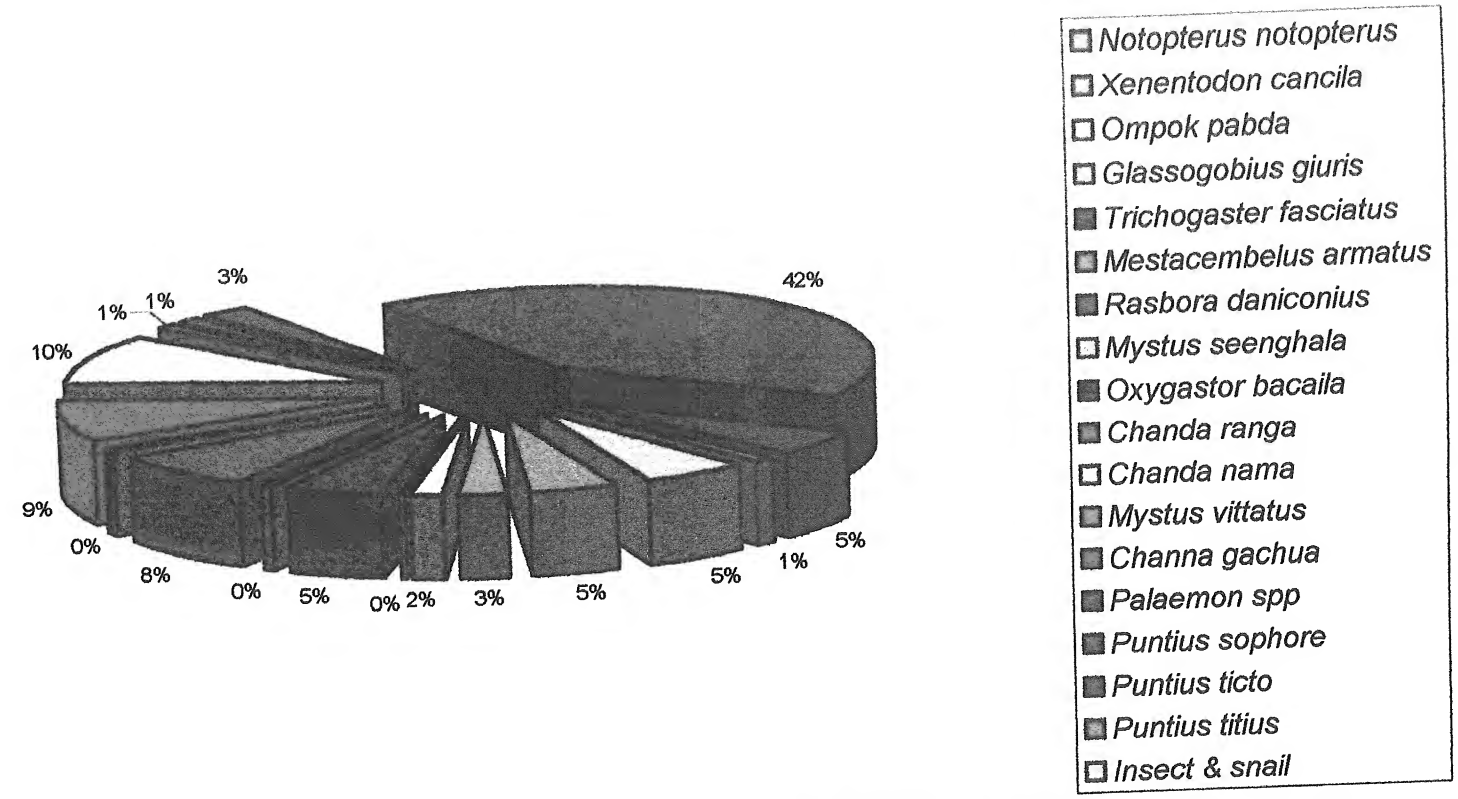


FIGURE-21 : Random sampling of weed fishes in Pahunj reservoir.

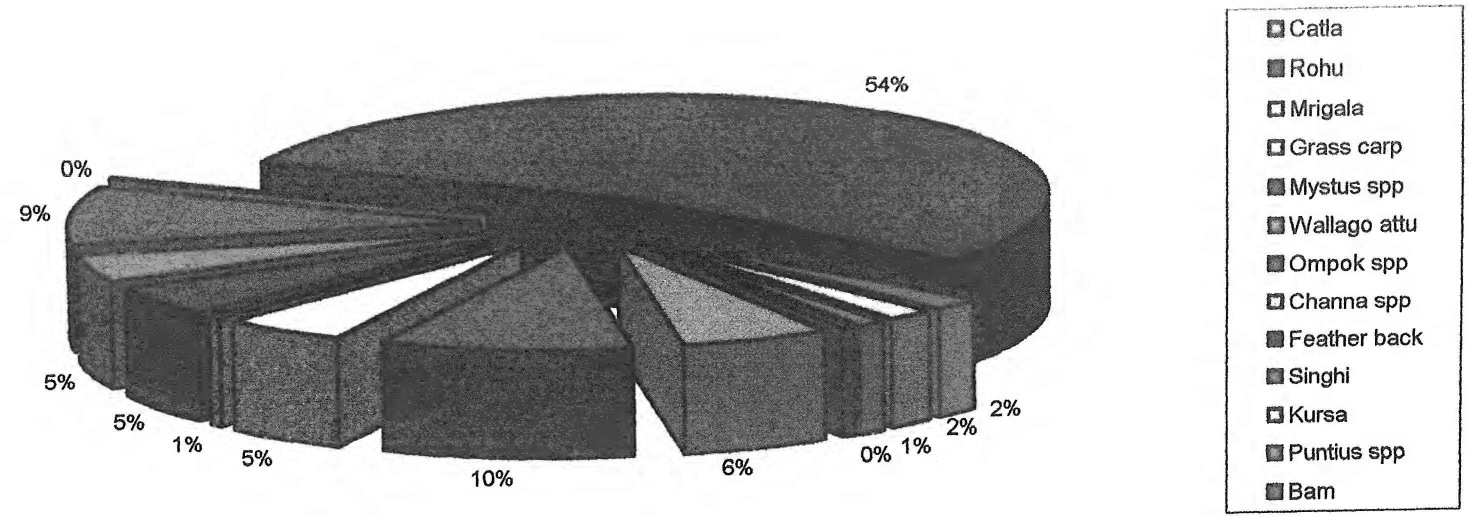


FIGURE-22 : Relative abundance of some commercial fishes in Pahunj reservoir.

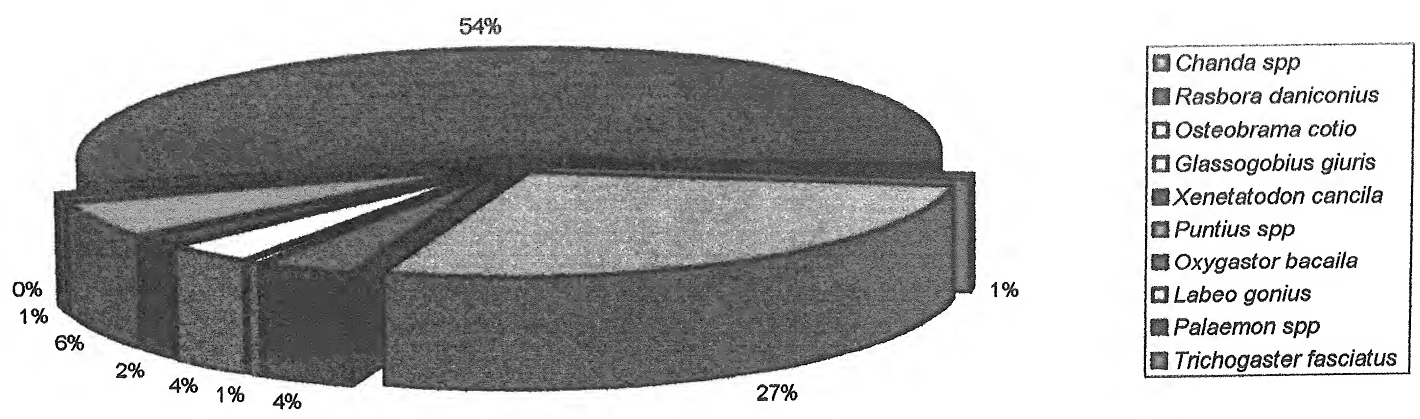


FIGURE-23 : Relative abundance of weed fishes in different samples in Pahunj reservoir.

Chapter -6

Primary Productivity

A. Observations

B. Discussion

A. Observations

Organic production starts with the synthesis of organic compounds from inorganic constituents by the activity of chlorophyll bearing plants in the presence of sunlight. The inorganic constituents which form the raw material for this synthesis are water, carbon dioxide, nitrate ions, phosphate ions and various chemical substances. The products are carbohydrates, proteins and fats. Organic production in plants is the first step in traping energy by living beings from non living natural resources and hence called primary production. Cholorophyll bearing microscopic organism such as phytoplankton , periphyton, algae and also macrohpyts serve as primary producers in aquatic chain. These communities play an important role in production process of reservoirs as fishes are mostly dependent on these biotic communities for their food. Factor influencing primary production are light, temperature, nutrient supply and grazing rates. The measurement of plankton productivity helps to understand the conversion ratio at various trophic levels and serves as an essential input for proper management of reservoir.

Estimation of primary productivity was done by using dark and light bottle method (Ggarder and Gran, 1927). Average gross primary productivity was 125.6mgC/hr/m^2. The net primary productivity was 95.43mg C/hr/m2(average). Further, conversion of these values from hourly to whole day period gives 1507.2mgC/day/m^2 and 1145.16mgC/day/m^2 figures respectively. This difference between gross productivity and net productivity is due to utilization of product in respiration by biotic communities present at that time. Net primary productivity was also estimated on the basis of oxygen uptake in dark bottle. It ranged between 5.20mg C/hr/m2 (Feb'93) to 182.29mg C/hr/m2 (June'95). The average net primary production was 95.43mg C/hr/m^2 while the corresponding values for the day was 1145.16mg C/hr/m^2. The difference between gross primary productivity and net primary productivity was 30.17mg C/hr/m^2 which represent the quantity consumed during respiration. Rate of respiration was also estimated to have an idea about energy flow. It ranged from 0.1mg O_2 /l to 1.9 mg O_2 /l. Gross oxygen production ranged from 1.0mg/lt (Feb'96) to 3.8mg O_2 /l (June'95) with an average range of 1.74mg O_2 /l 6hrs or 3.48 mg/l/day(Table 17). Primary Productivity values exhibit seasonal varitaion. It was maximum

during June' 95. Onset of monsoon causes decline in productivity till september (figure 24). It begins to increase from October to December. This increase manifest itself in the form of the winter plankton pulse. Excessive cold in late December and January again adversely effects the gross primary productivity sliding down to 10.16 mgC/hr/m2 in January'96 and 52.08 mg C /hr/ m2 in February '96. Favourable climatic conditions in March and following months boost the plankton production when it increases upto 1237 unit/l. Phytoplankton fairly contribute (about 71.22%) during this period. It shows related dependence of productivity over phytoplankton population.

B. Discussion

Biotic communities play an important role in production process of reservoirs as fishes are mostly dependent on these communities. Climatic, edaphic and morphometric features of reservoir play a crucial role in metabolic exchange. The measurement of plankton productivity, both at primary and secondary level, is essential for proper management of reservoirs. The success of an organism and its productivity in reservoir ecosystem are determined in part by suitability of environment. The most obvious aspects are temperature, concentration of dissolved oxygen, the ability to produce food organism and nature of substratum. Temperature and light influences activity from molecular to an organismal scale. The general positive effect of temperature on primary production is the result of reproductive biology of plankton and benthos. Many workers suggested that with the increase in the temperature growth rate and feed rate also increases. Pidgaiko et. al. (1972) concluded that temperature variation could have either a positive or negative effect on productivity of biotic communities depending on geographic location and basin morphometry of reservoir. In the present case maximum primary production was observed in June' 96 when highest temperature and penetration of light occurs. According to Macan (1961) metabolism in animals and plants reaches upper most limit at 36^{0}C. Further increase in temperature adversely effects it and sets declination. Calculated values for primary production confirms this aspect. Decline in primary production during monsoon period when favourable temperature occurs, is probably due to inflamation of other limiting factors. The two plankton pulses i.e. winter and summer coincides with favourable temperature regimes supported by other required inputs. Verduin (1957) has reported higher values in subdued light. It appears that production goes on at moderate rate throughout the period of study except in chilly winters. Contrary to this Sreenivasan (1964) reported high production values in poor light conditions. The corresponding values for primary productivity at 0.6 mg/l nitrate level was 197.91 mgC/6 hr/m^2. It fluctuates with change in Nitrate concentration. Nitrate concentration begin to increase from 0.32 mg/l (Feb'96) to 0.70 mg/l (June'96). Gross primary production also increases from 52.08mgC/hr/m^2 to 130.20mgC/hr/m^2 in this period. Phosphate is another nutrient which frequently

becomes limiting factor in otherwise nutritive waters. In the present case phosphate concentration ranged between 0.065 mg/l 0.72 mg/l with an average of 0.32 mg/l. It is observed that phosphate remain lower in monsoon and winter while higher in spring and summer. During these periods corresponding values of gross primary productivity was 127.59mgC/hr/m^2 (Winter average) and 153.64mgC/hr/m^2 (Spring average). This confirms dependability of GPP over phosphate ions.

Khan (1997) and Murugesan (1997) studied primary productivity in Bachhra and Trimurthy Reservoirs. Khan (1997) reported two plankton pulses appearing in late monsoon and spring seasons. While Murugesan (1997) reported primary productivity about 894.1 mgC/m2/day. Average primary productivity for Pahunj reservoir is 125.6mgC/hr/m^2 with two distinct plankton pulses. It indicates that the water body under investigation possesses high potential of productivity.

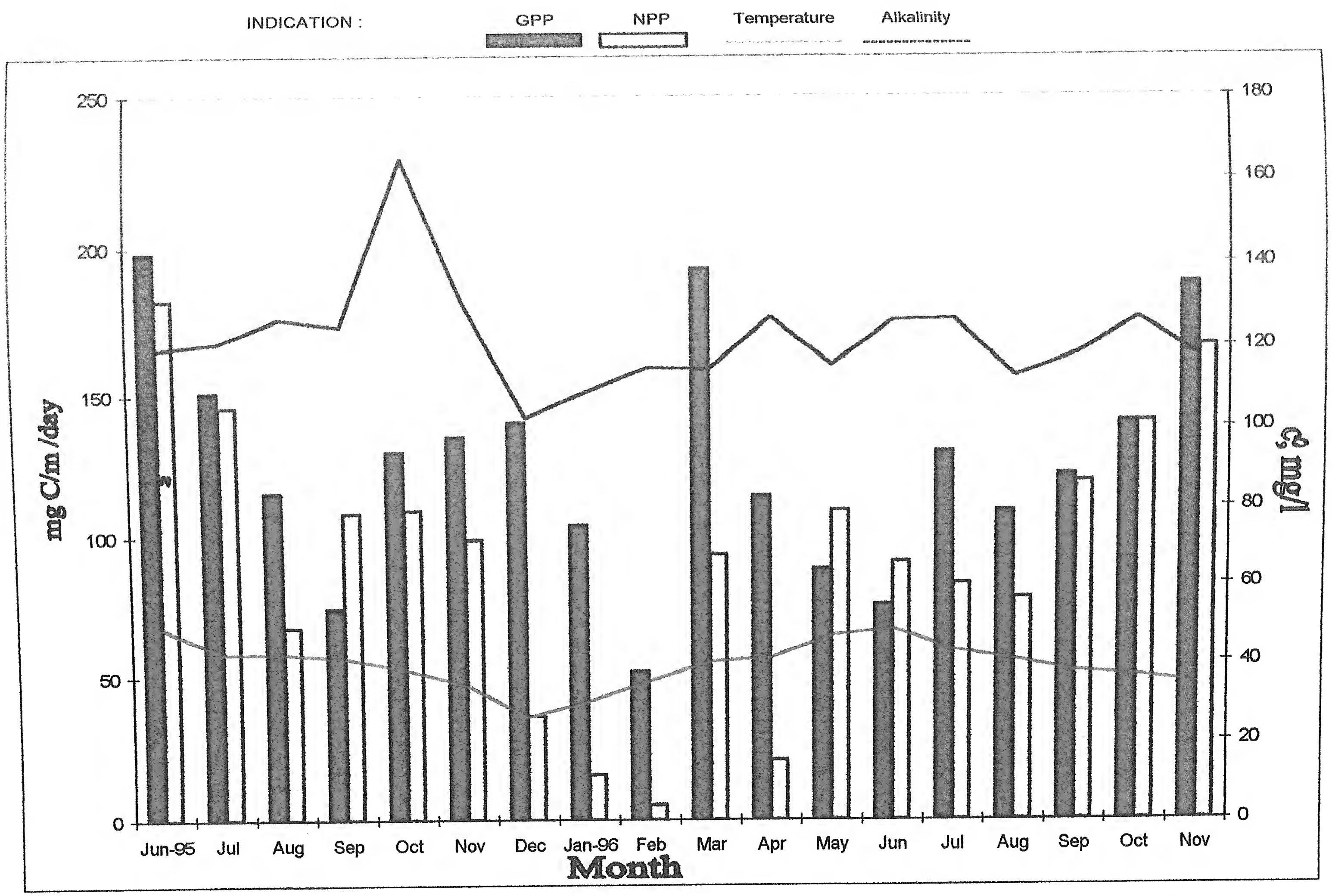


FIGURE-24 : Seasonal variation of gross primary production (GPP) and net primary production (NPP) along with temperature and alkalinity.

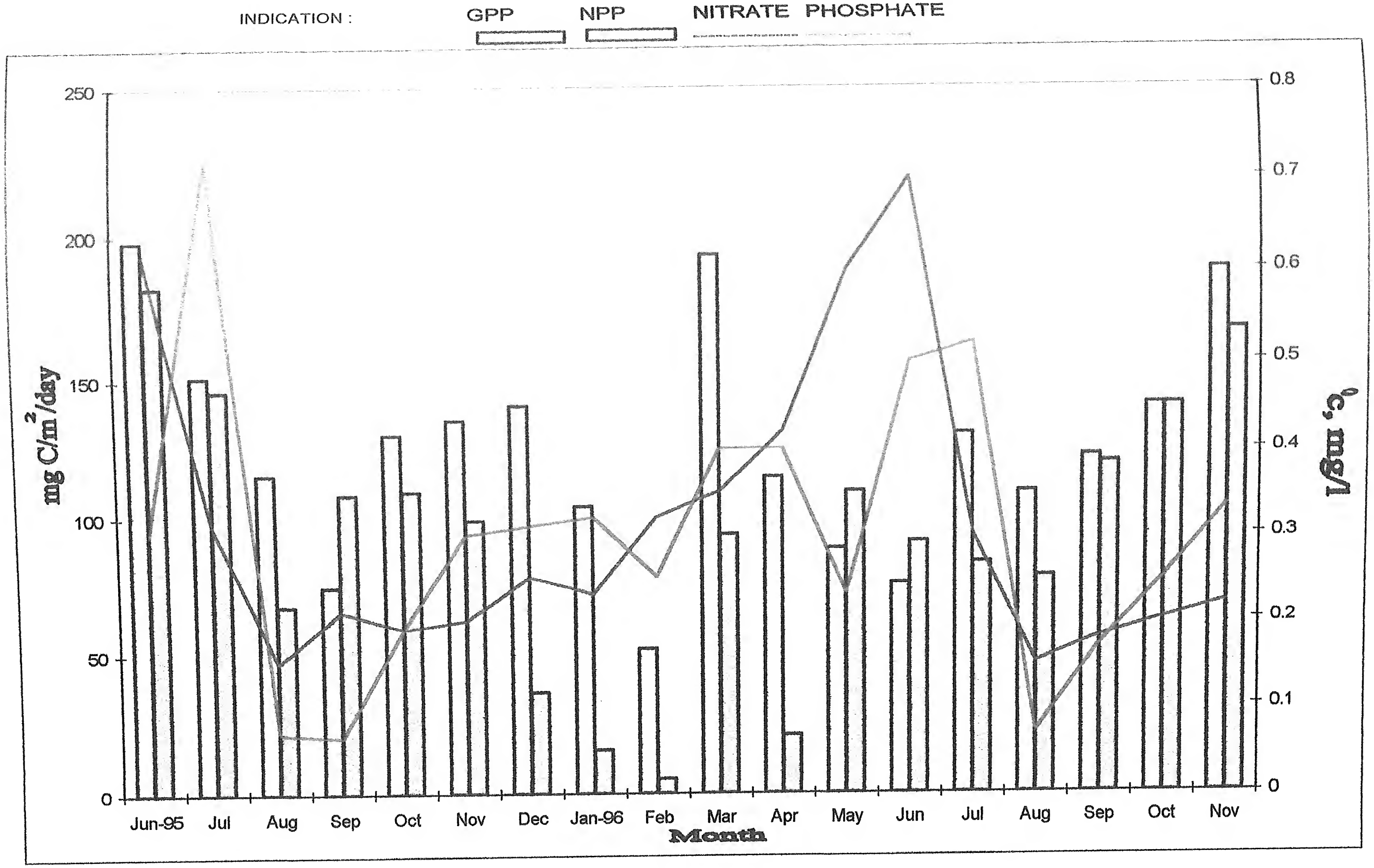


FIGURE-25 : Seasonal variation of gross primary production (GPP) and net primary production (NPP) along with nitrate and phosphate.

Chapter -7

Fish Stock Assessment

A. Observations

B. Discussion

A. Observations

By Schaefer and Fox model : The regression of fish yield per effort (y/f) in kg on annual effort, f, in men/day and boats/day for the period of 1970-71 to 1979-80 and 1971-72 to 1982-83 (Excluding 1973-74 and 1974-75) respectively has been found to be,

$$\text{Schaefer : } y/f = 6795.42 - 289.897\, f;\ r = 0.703 \text{ and } r^2 = 0.50$$

$$\text{Fox : } y/f = \exp^{(7.190624003 - 0.01976\, f)};\ r = 0.975 \text{ and } r^2 = 0.95$$

where f stands for men/day.

$$\text{Schaefer : } y/f = 3937.1040 - 61.2659\, f;\ r = 0.421 \text{ and } r^2 = 0.18$$

$$\text{Fox : } y/f = \exp^{(8.167927144 - 0.4317869\, f)};\ r = 0.482 \text{ and } r^2 = 0.23$$

where f stands for boats/day.

The annual maximum sustainable yield (MSY) was estimated to be 33.101t fish (schaefer), 24.658t fish (Fox) for maximum effort (f_{msy}) of 11 men/day (Schaefer) and 50 men per day (Fox) respectively. The annual MSY is estimated to be (efforts/day) 632.532t fish (Schaefer) and 29904 kg (Fox) for f_{msy} 32 boat per day (Schaefer) and 23 boats per day (Fox) respectively(Table 23).

The coefficient of correlation 'r' was 0.703 (Schaefer) for an effort in men per day (mpd) and 0.95 (Fox). The coefficient of correlation 'r' was 0.421 (Schaefer) and 0.482 (Fox) for an effort in boats per day (bpd).

Estimation of Maximum economical yield (MEY) : Estimation of MEY on the basis of price per unit weight of fish, P, as a function of yield or supply for commodities, where prices are determined by market forces. P is a monotonically decreasing function of fish yield (Y). The price function to the economic data is found to be,

$$P = 1.6962 - 0.00001969\, Y$$

The profit function for operational cost is,

$$\text{Profit (p)} = 1.6962 - .00001969\, y2 - 0.50\, y$$

The MEY for operational cost has been estimated to be 30.377 t Fish for f_{mey} of approximately to mpd. The MEY of 30.377 t is very near to MSY of 33.101 t fish. The cost to generate the fish, the MEY is estimated by assuming the contractor spent 25% of royalty to fishermen as a labour

cost and operational cost.

Estimation of fish yield by Trophodynamic model : Malack (1976) fitted fish yield (FY) in kg/ha/year as function of gross primary productivity (GP) in go_2 /m²/day for 15 ponds, tank and stream in India which follows,

$$\log FY = 0.95 + 0.122\ GP$$

If this equation fitted in Pahunj reservoir the fish yield/ha will be (The GPP is 4.0192 go2/m2/day)

$$\log FY = 0.95 + .122 \times 4.0192$$

$$\log FY = 1.4403424$$

$$FY = 27.56\ kg/ha$$

Fish biomass estimation by primary productivity : The net primary production was estimated to be 95.43 mgC/m²/hrs (Table 17) or 1.14516 gC/m²/day which is 75.98% of GPP against the 8% according to Gnaff (1972, 74). At this value annual carbon production in Pahunj reservoir for 518 ha area is estimated to be 2165.154 t equivalent to wet biomass of 1,617.30047 t. If 1% primary production is considered to tertiary biomass, the weight of tertiary biomass would be about 1.61.7370047 t which is approximately 11 times of average annual production of 14.623 t fish. Estimated total fish biomass represent 9.99% of primary production.

B. Discussion

A population in a particular ecosystem may be defined as a functional unit which responds to a number of natural and artificial forces operating in that ecosystem. Size of a population at any given time may be taken as a index of operating forces which act upon that unit. The ultimate size of a population is determined by these forces namely natality, mortality and dispersion. Natality always exerts positive impact while mortality is a negative aspect and dispersion may have either negative or positive effect depending upon its nature i.e immigration or emigration. In optimum ecological conditions and absence of human intervention, a population grows to maximum size commensurating the carrying capacity of that ecosystem. Exploited populations seldom attain this level. The actual size being a function "interalia" of the intensity of exploitation (Devaraj, 1983).

Fish population of any self sustaining water body depends on its carrying capacity, recruitment and mortality. Carrying capacity is the result of primary production and its storage in the form of chemical energy and energy conversion efficiency at various trophic level by consumption. Recruitment includes increase in number either by natural breeding or immigration and seed stocking. Mortality is decrease in number either due to natural forces or commercial fishing. Primary production and natural recruitment are constant factors. While the mortality and seed stocking are variable factors which can be used to manipulate the fish population. Fishing pressure should be to a such extent that recruitment must tolerate it to keep desired biomass so it can be ready for future exploitation. This available biomass is biological optimum yield or sustainable yield which can be harvested on long term basis without disturbing the minimum desired stock. Hence stock assessment is very essential for developing reservoir fishery by augmenting natural recruitment through an approximate stocking policy(Devaraj, 1983). According to Ramakrishnana (1990) a prior approximation of fish yield potential is essential to have an idea of expected harvest before large scale management measures are taken up. The maximum sustainable yield (MSY) which is considered to be biologically optimum yield estimated by surplus model, was originally designed to marine fishery but later on applied on fresh waters by Devaraj

(1983). This model is based on the fact that the yield per effort is monotonically decreasing function of effort. The reservoir fishery is the combination of both capture and culture fisheries. Whenever the capture fisheries operates in larger water bodies, there is an inevitable need for assessing the stock of both the local and transplanted species and determination of the optimum level of fishing in order to sustain the benefits on long term basis (Mahesh, 1989).

According to Schaefer (1954) model annual MSY is estimates to be 33.101 t fish for effort in 11 men/day (mpd) and 63.252 t for f_{msy} 32 boats/day (bpd). According to Fox (1970) model the annual MSY is estimated to be 24.658 t for f_{msy} 50 mpd and 29904 kg for f_{msy} 32 bpd (Table 23)

The coefficient of correlation 'r' is 0.703 for estimated MSY of 33.101 t fish for f_{msy} 11 men/day, 0.421 for MSY 63.252 t fish and f_{msy} 32 bpd, 0.95 for MSY 24.658 t and f_{msy} 50 mpd, 0.482 for MSY 29.904 t and f_{msy} 23 bpd. The coefficient of correlation 'r' is higher for MSY 24.658 t and f_{msy} 50 mpd. However when the data between absolute yield per effort versus efforts were plotted on the basis of equations (Fig 26,27) and observed value, are more nearer for Schaefer model for effort in men/day. Hence MSY 33.101 t for 11 mpd in this reservoir is more appropriate and should be used for management. According to Schaefer(1954) the total fish stock in water is double of MSY, hence the total fish stock is Pahunj is 66.202 t.

The maximum economic yield is estimated 30.377 t for f_{mey} 10 men/day. Economic profit (Producer's surplus) will be at maximum hence only 10 men/day should be allowed if contractors/ government agency wants profit maximisation.

The Pahunj reservoir has an area of 518 ha at full reservoir level and gave an average fish production of 43.57 kg/ha/yr (1965 to 1980). The annual fish catch ranged from 4.812 t (1979-80) for fishing effort of 11 men/day to 29.364 t for fishing effort 14 mpd. The annual average fish yield from this reservoir was 14.623 t for an average fishing effort of approximately 18 men/day, indicating that. there is a wide gap between average annual catch of 14.623 t and MSY of 33.101 t or maximum economic yield (MEY) 30.377 t for f_{mey} (effort at MEY) 10 men/day. So there is need to lower the fishing effort to 11 men/day from average annual 18 mpd to attain the MSY of

33.101 t fish on long term basis. If profit maximisation is prime objective, the effort should be 10 men/day.

Exploitation of fishery in this reservoir started from 1965-66 when royalty system was prevailed where contractor had to pay royalty against fish catch of different varieties. There was no restriction on efforts. Therefore, initially the catch was 47.860 t in 1965-66 for an effort of 24 mpd. But the reservoir was over exploited by unrestricted efforts leading to decline of catch to 8.627 t/yr only. For next three year (1969-71) the fish yield was around 27.000 t which was slightly lower the MSY (33.101 t) and average annual effort was higher (15 mpd) then f_{mey} (11 mpd). This is also a level of overexploitation of reservoir. From 1971-72 to 1980-81 the effort was higher then the f_{msy} every year (Table 21) hence the MSY could never achieved.

On the basis of primary production the fish stock estimated to be 1,61.737 t/yr which is in principle, the carrying capacity of the reservoir. The stock represents 9.99% conversion from primary to tertiary production which is very high in comparison to other reported values. It is 1.5% in equatorial lake of Georgea and 1.2% for the North sea where secondary consumer are predominant (Malack,1976). The maximum fish yield form Pahunj reservoir achieved 73.066 t with 0.82 million fish seed stocking which represent 4.90% conversion from primary production to tertiary production and is indicator of high eutrophication of reservoir. This ratio can be compared to 4.43% in Bundh baretha of Rajasthan (Mahesh and Devaraj, 1990). The estimated fish stock 161.737 t can be achieved by further higher stocking rate and species management. In Pahunj Planktivores contribute 7.3%, omnivores 75.48%, Second level carnivores 7.3% and Third level carnivores 5.84%, hence the energy transformation is through predominantly by omnivores which are very efficient users.

According to trophodynamic model (Malack,1976) the yield per hectare is estimated 27.56 kg/ha by which the fish stock in this reservoir would be 142.7608 t fish. This figure is very near to annual average of 14.623 t but 1996-97 142.618 kg/ha have already achieved in this reservoir by heavy fish seed stocking. Carrying capacity in this reservoir is 161.737 t and MSY is 33.101 t. On the basis of MSY the fish stock should be 66.202 t while there is wide gap between carrying

capacity of reservoir and fish stock. Hence to utilize the total carrying capacities the reservoir should get stock enhancement with the Indian major carps and other suitable exotic carps. Reservoir has a lower secondary level of omnivore population to utilise the snail, worms, insect and other secondary products. Hence the stocking of reservoir by economically valuable secondary level carnivores like *Pangassius pangassius*, *Ompok pabada*, may be useful.

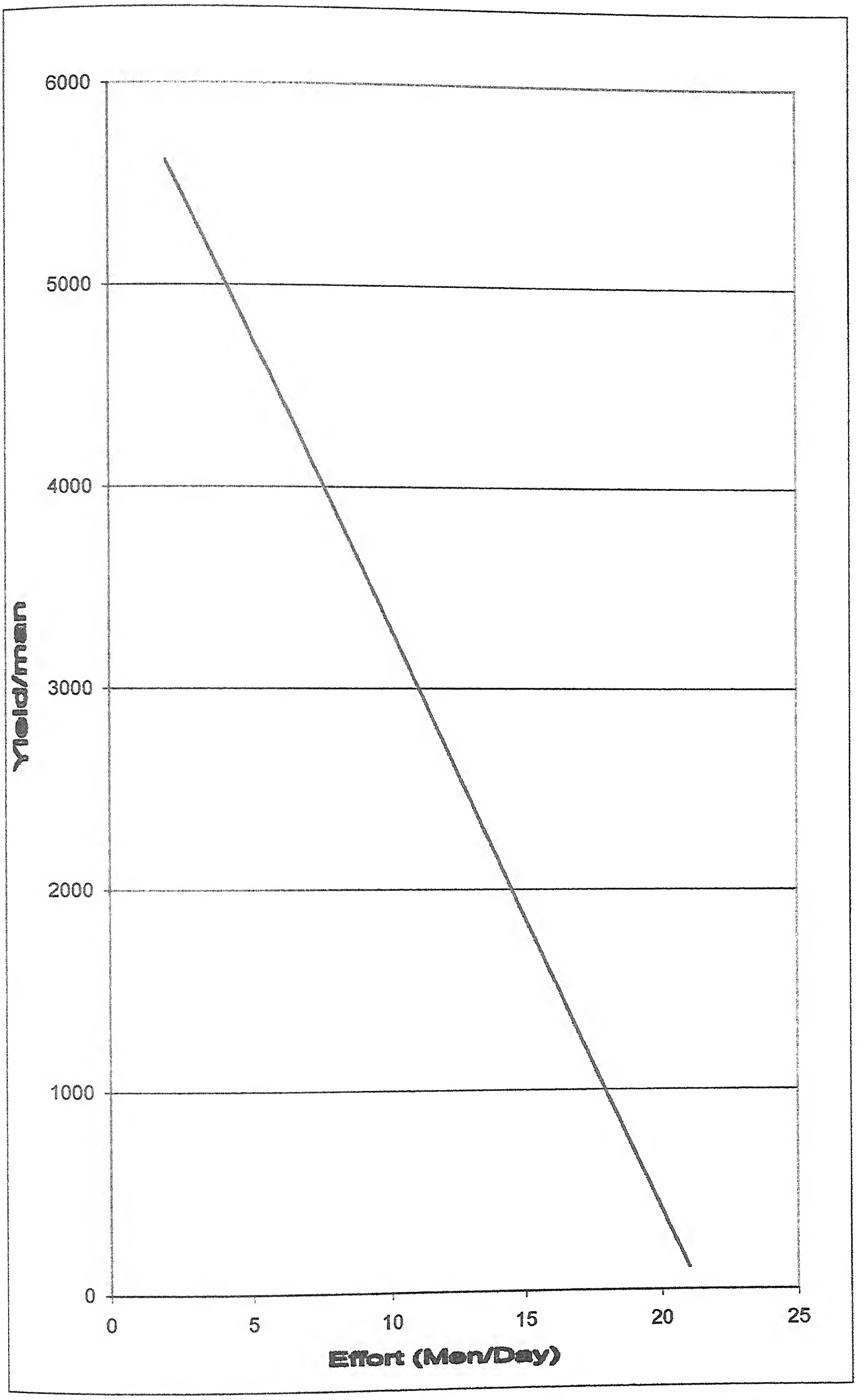


FIGURE-26 : Yield/Effort (Y/f) in relation to Effort (Men/Day) according to Schaefer model.

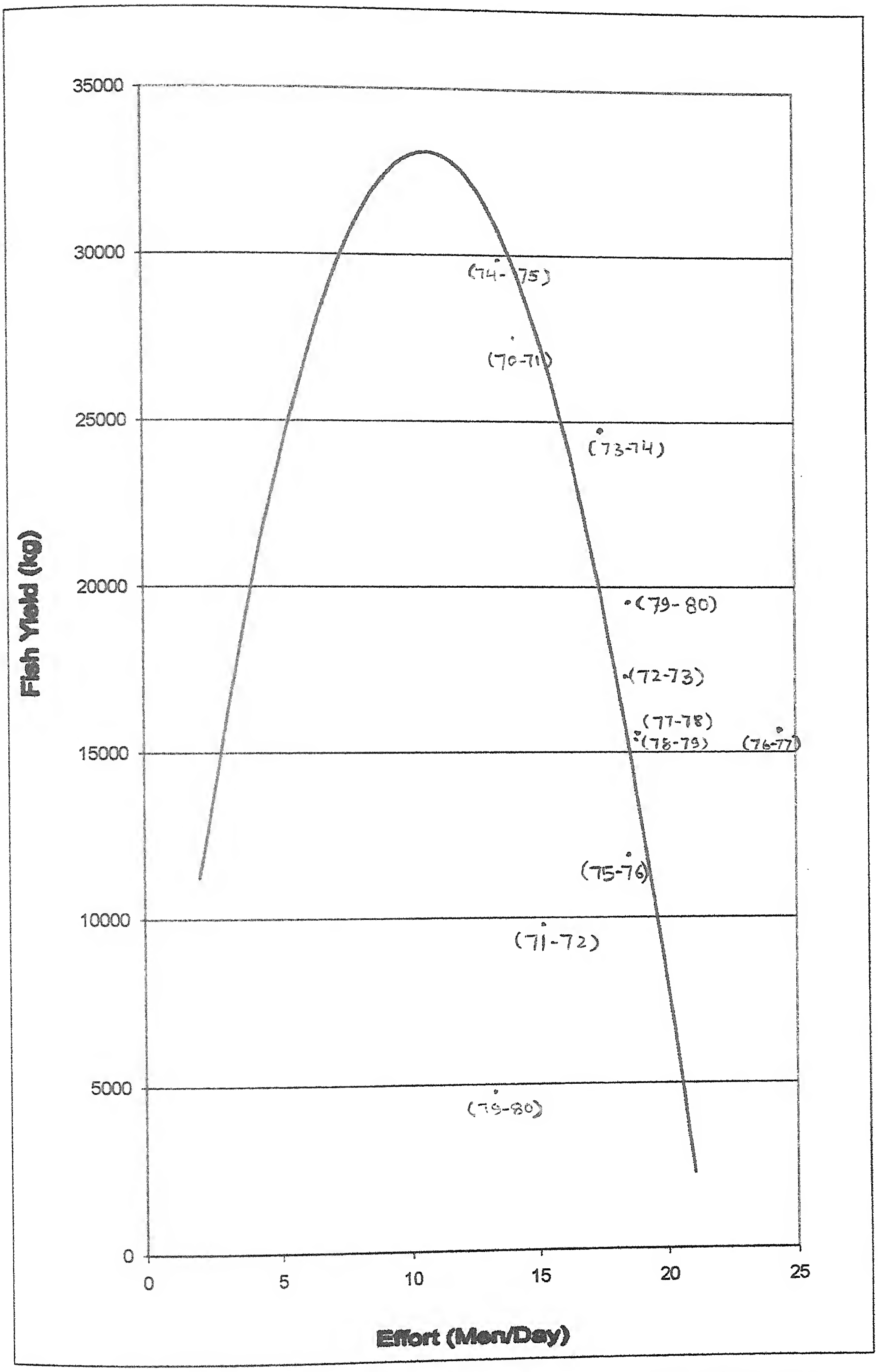


FIGURE-27 : Fish yield in relation to Effort (Men/Day) according to Schaefer model compared with actual fish yield.

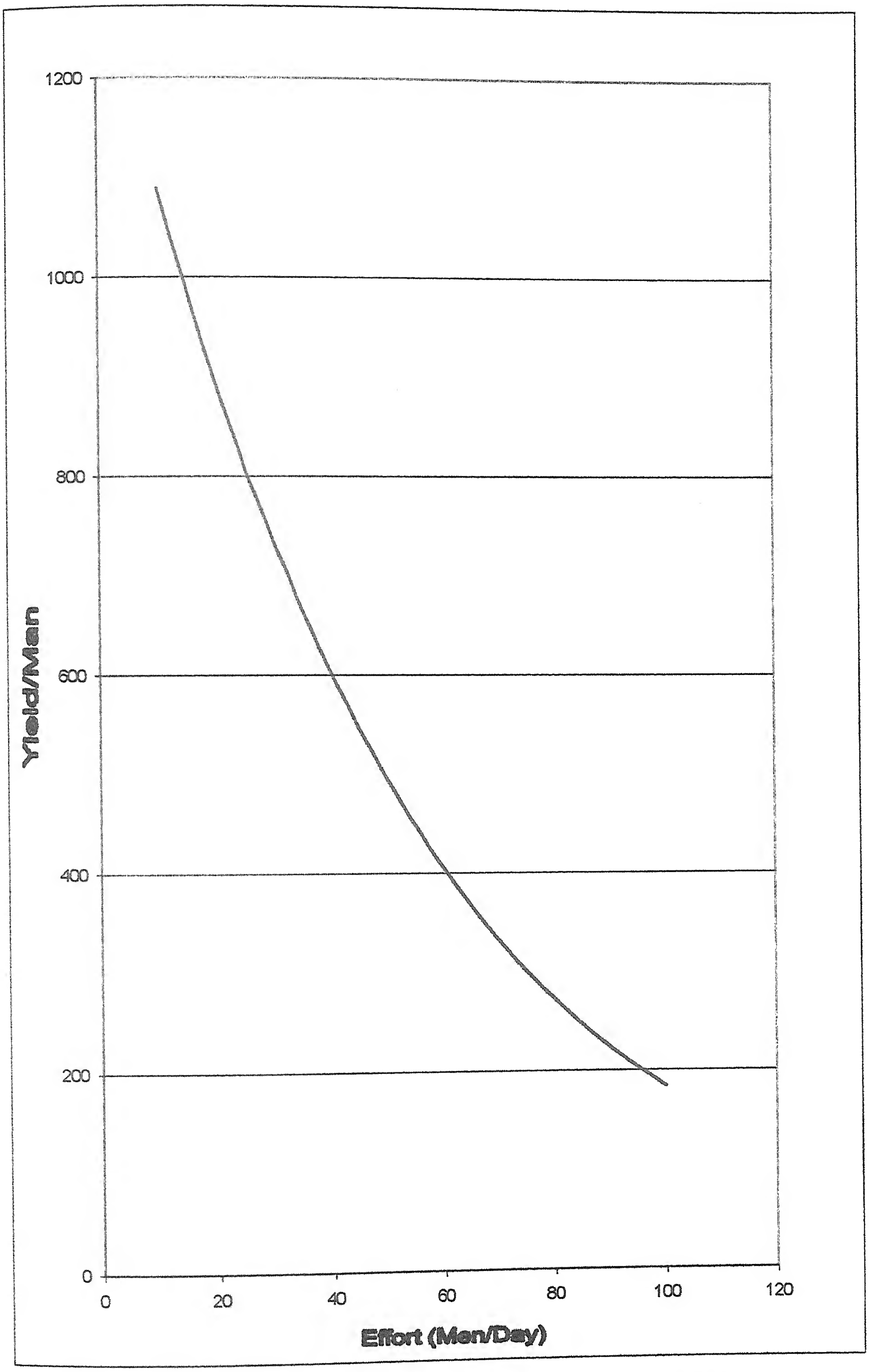


FIGURE-28 : Yield/Effort (Y/f) in relation to Effort (Men/Day) according to Fox model.

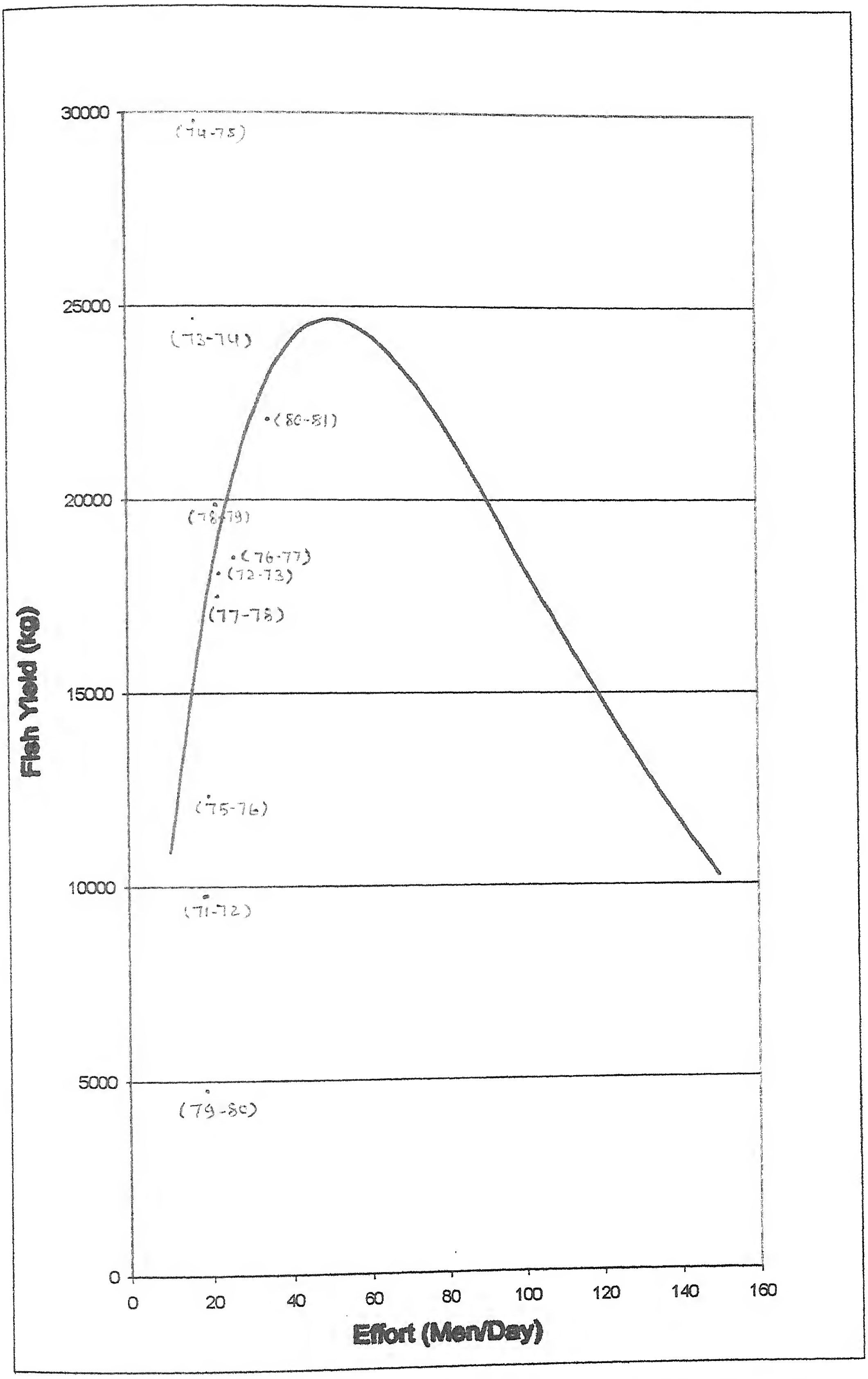


FIGURE-29 : Fish yield in relation to Effort (Men/Day) according to Fox model compared with actual fish yield.

INDICATIONS : Schaefer Fox

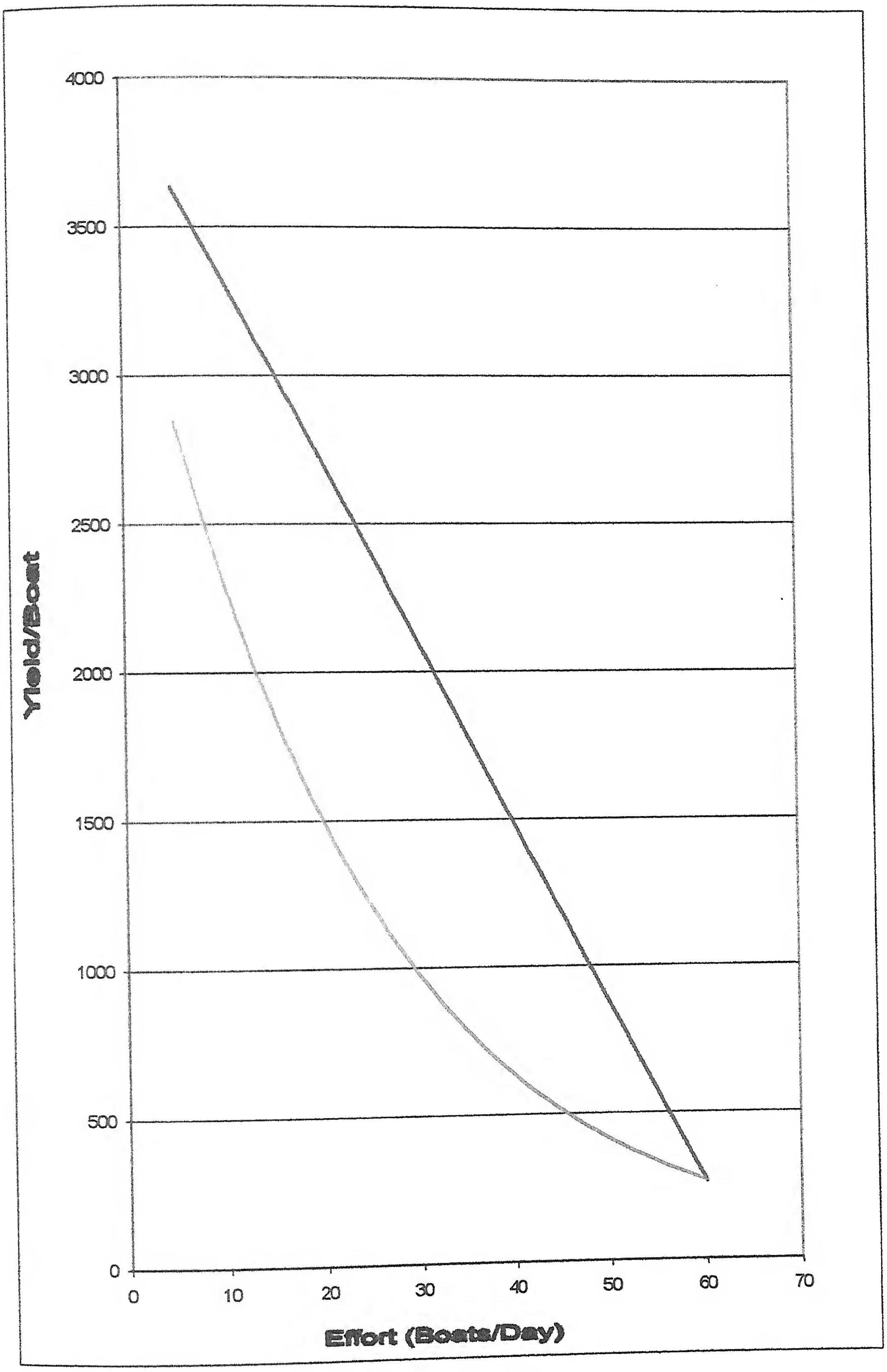


FIGURE-30 : Yield/Effort (Y/f) in relation to Effort (Boat/Day) according to Fox and Schaefer model compared

INDICATION : Schaefer ——— Fox ———

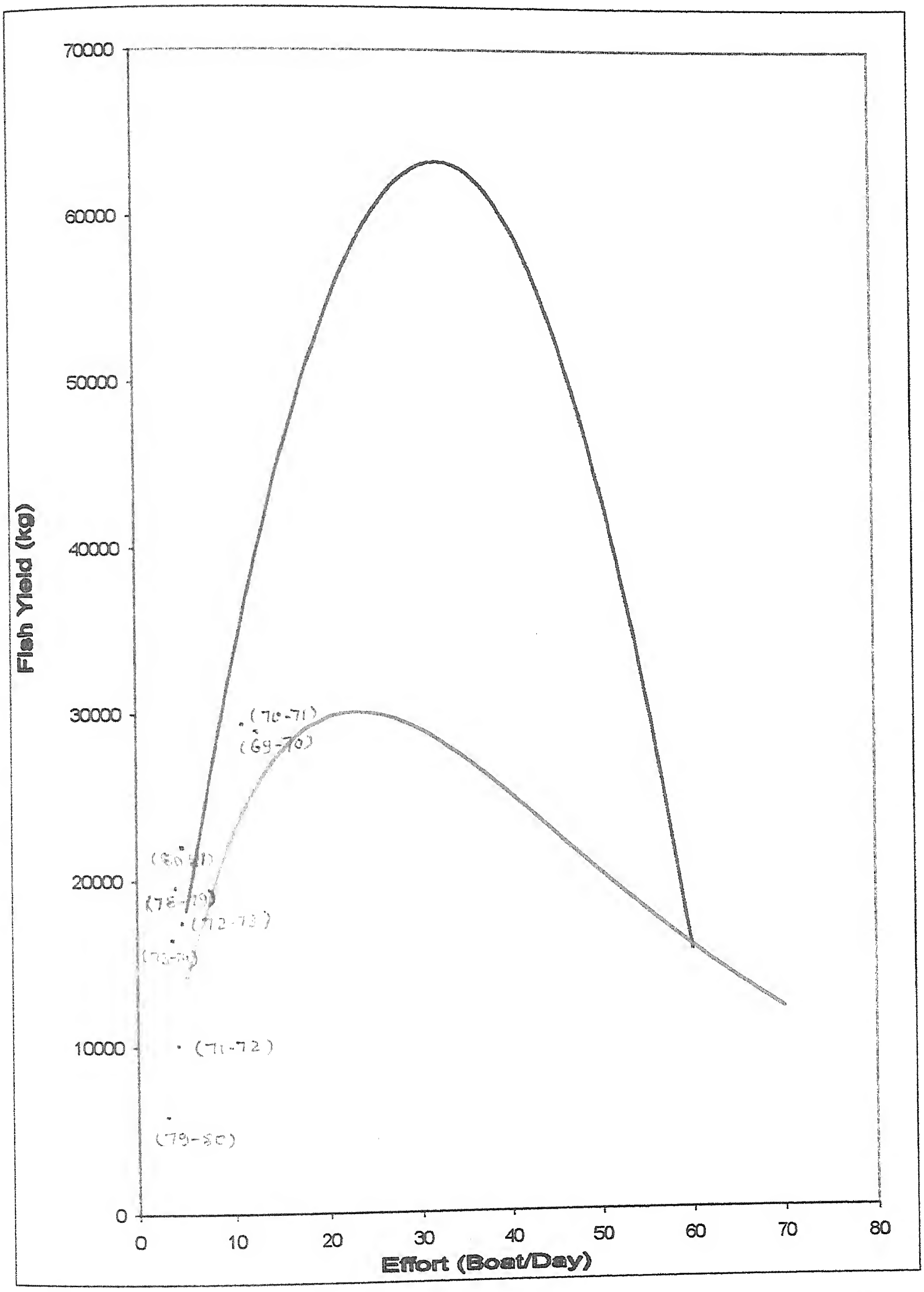


FIGURE-31 : Fish yield in relation to Effort (Boat/Day) according to Fox and Schaefer model. Compared with actual fish yield.

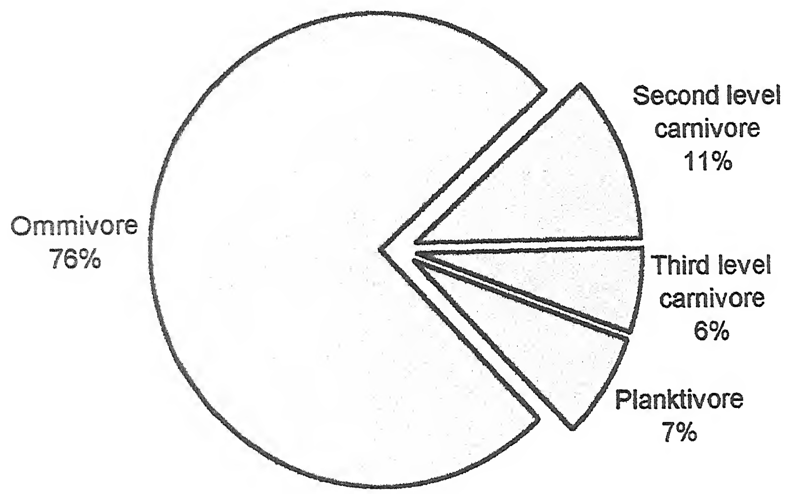


FIGURE-32 : MSY split up into feeding categories for Pahaunj reservoir

Chapter -8

Commercial Fishery

A. Observations

B. Discussion

A. Observations

Fishing system : Organised fishing for commercial exploitation of this reservoir commenced from 1965-66 when Fisheries department (UP) conducted an exploratory survey to collect base line information. Initially from 1965 to 1984 royalty system based on category wise weight was adopted but later on outright auction on quota system was enforced from 1985. Under this system category wise catch quota was fixed where category 'A' represent major carps (>1.5kg), while category 'B' major carps (<1.5kg). Category 'C' has catfishes, murrels, feather back and other carnivores. Category 'D' represent minor carps and other weed fishes. After 1995 this system was abolished and free fishing except undersize exploitation was allowed.

Fishing unit : Contractor usually employ different types of traditional fishing units for overall exploitation of fishery wealth. The main categories of fishing units are (1) Gill nets generally 10-20 gill nets are used by two fishermen with a boat of 12" size (2) Mahajal units consists of 2-3 boats and 10-15 men (3) Dragnet (chatti) 'A' 40-50 meter net used by 10-12 men and 3 boats (4) Purse siene (Fasy), 12 men and 2-3 boats (5) The Kanta party consists 20-25 fishermen and 3-4 boats operated only in summer seasons, when water level is very low, the net is fitted in a narrow cove ("nalla") to completely cut from mother reservoir and operation is over in 10-15 days. All the fishes present in the cove are accumulated in small space. (6)The long lines know as "Katia" are used to catch cat fishes and carnivore fishes. The other nets used in reservoir are scoop net and cast net operated by one fisher men in shallow region.

Yearly variation in fish yield : Taking 1965-66 as the base year, the annual fish yield progressively decreased (Table 21). It was 47.868 t in 1965-66 and very low 86.27 t in 1967-68; 9.690 t in 1971-72 and 4.812 t in 1979-80. The average fish yield is to be 22.569 t/year (1965-1981-82). During 1984-95 the average fish yield was 17.0 t 1995 to 1998 the fish yield increased 30.1 t and reached 73.890 t in 1997-98 and again declined to 50.8 t in 1998-99 (Table 21).

Fish yield per hectare : Average Catch 43.57 kg/ha was obtained for 16 year (1965-66 to 1980-81). The fish yield show a specific pattern. It was 92.39 kg/ha in 1965-66 and declined to 16.65 kg/ha in 1967-68. It fluctuated between 52.86 kg/ha to 55.27 kg/ha from 1969-70 to 1970-71

and touched down 18.70 kg/ha in improved to 32.54 kg/ha, 46.33 kg/ha, 56.68 kg/ha in 1972-73, 1973-74, 1974-75 respectively. It was almost constant from 1976-77 to 1978-79. Again in 1979-80 it was lowest 9.29 kg/ha (Table 21). The average fish productivity for quota system (1984-95) was constant with little variation depicting average values of 29.15 kg/ha (1989-90 to 19995-96). Under quota free system, the productivity increased from 58.10(1995) to 142.0 kg/ha(1997-98).

Fish catch structure : Fisheries department (UP) has maintained category wise production records. The category A and B together fluctuated between 0.22% - 37.6%. These were 8.0% in 1965-66 and dial between 5.8% (1969-70) - 12.5% (1971-72), became very low when they contributed only 1.46% in 1972-73. They steadily increased from 6.35% (1973-74), 16.23% in 1974-75 and reached to 37.6% in 1976-77. During quota system, their contribution was around 12.5% and registered an increase upto 35.5% in 1991-92. However they sustained themselves at the level of 26.38% (1992-93) and 29.87% (1993-94). Due to complete drying of this reservoir in 1995 this category faced a complete jolt having only 0.50% representation. Later on under quota free system (World Bank Project) heavy fingerling stocking increased this category to 43.65% in 1997-98 (Table 25,26 Fig. 33,34).

The category 'C' fishes contributed 44% in 1965-66 and followed an increasing trend upto 51.6% in 1967-68. Further this trend reversed and production declined to 29.77% in 1968-69, 13.58% in 1970-71. It fluctuated from 27.02% to 32.55% between 1971-72 to 1973-74. However, this category shared maximum production percentage of 68.69 in 1977-78. It further fluctuated between 23.61% (1992-93) to 54.06% (1991-92) with the average 31.90%. During 1989-90 to 1995-96 it showed little variation. Water scarcity during 1995-96 also depleted this category upto 2.99%. (Table 25,26 and Fig. 33,34).

Category 'D' (Minor carps and weed fishes) which compete with major carps for food and space were found 24.90% in 1978-79 and 77.03% in 1970-71 with the average 50.1% in catch for 1965-66 to 1980-81. These show increasing trend during 1971-72 to 1973-74 period from 66.1 to 66.97% and a reversed trend between 1976-77 - 1967-77 (37.5% - 24.96%).

Detail species composition was work-out, for stipulated periods extending upto 10 years, (1971-72, 1974 to 1976, 1989 to 1991 and 1995-96 to 1998-99) on the basis of daily catch data. Species wise average annual catch composition was, *Catla catla* 7.34% (Nil to 14.63%), *Labeo rohita* 10.75% (0.2% - 21.58%), *cirrhinus mrigala*, 7.32% (0.3 - 15.34%), *Labeo calbasu* 0.21% (nil - 0.44%)., *Labeo bata* 0.097% (Nil - 40.49%) *Wallago attu* 4.17% (0.71% - 17.16%), *channa spp* 1.67% (0.03 - 10.77%), *Mastacembalus armatus* 0.70% (Nil - 2.41%), *Mystus spp.* 7.64% (1.1 - 18.85%), *Ompok spp.* 0.53% (Nil - 2.41%), *Notopterus notopterus* (0.01% - 17.65%), *Puntius sarana* 9.35% (Nil - 40.49%) and other miscellaneus weed fishes 44.35% (0.45% - 96.41%); (Table 27).

Random sampling was carried out to determine the composition of weed fishes in "Chatti" (dragnet). The fishes were small *Notopterus notopterus* 4.5%, *Xenentodon cancila* 2.5%, *Ompok pabda* 1.5%, *Glassogobius giuris* 4.4%, *Trichogastor faciatus* 5.0% *Macrognathus acculetus* 0.4%, *Rasbora daniconius* 8.0%, Juveniles of *Mystus spp* 0.3%, *Oxygastor bacaila* 0.3%, *Chanda ranga* 9.0% *Chanda nama* 10.0%, *Mystus vitatus* 1.0%, *Channa gachua* 1.2%, *Palaemon spp.* 1.2%, *Puntius sophore* 42%, *Puntius ticto* 5.0%, *Puntius phuntunio* 1.2%, insect and snail 5.2% (Table 28).

Fishes were grouped according to their feeding habits to know the mode of energy transformation at various levels. The planktivores constituted 7.3% with the annual average catch 1.640 t/yr, omnivores 75.48% with the average 16.869 t/yr, third level carnivores 5.84% with the average annual fish catch of 1.306 t/yr and second level carnivores 11.34% with 2.534 t/yr(Table 24). Among strictly planktivore species only *Catla catla* was found. The omnivores were represented by several species e.g. *Labeo rohita*, *Cirrhinus mrigala*, *Labeo gonius*, *Puntius sarana*, *Labeo calbasu* and other carps and weed fishes. *Puntius spp.*, *oxygastor bucaila, Chanda nama, Chanda ranga, Cirrhinus reba, Glassogobius guiris, Palaemon spp, Trichogastor faciatus* etc. Second level carnivores were *Mystus and Notopterus spp.* while *channa spp.* and *wallago attu* were third level carnivores. The planktivores represented 1.05% in 1971-72 to 4.8% in 1976-77, 1.57% - 5.49% during 1989 to 1991-92, and nil - 14.63% during 1996-96 to 1998-99.

The annual average was 7.34%. The omnivores were 54.79% in 1971-72 increased to 70.75% in 1976-77 and were 80.97% and 81.53% in 1989-90 and 1990-91 respectively. It slightly declined in 1991-92 with 73.41% but increased (97.45%) in 1995. Different species among omnivores show considerable variation in their abundance and interspecific competition . The third level carnivore (TLC) were 17.16% in 1971-72 and decreased to 14.51% in 1974-75, 5.5% and 4.39% in 1975-76 and 1976-77 respectively. The *Wallago attu* was the dominant species among TLC. The second level carnivore was 27.0% in 1971-72 and declined to 17.83% in 1975-76. Share of SLC was dialled between 10.67% (1990-91) to 16.0% (1991-92) and 5.10% (1998-99) - 10.45% (1995-96). Among the SLC the dominant group was *Mystus spp.* and *Notopterus notopterus* which contributed enmass and alternately dominated each other.

Incidentally entire Pahunj reservoir dried during 1995 summer leaving 1-2 ha shallow water area which resulted in complete elimination of fishes. Therefore species composition in later year was also analysed to know the consequences of exceptionally unusual phenomenon on fish fauna. It is observed from the comparative catch composition between 1994-95 and 1995-96, that *Catla catla, Mastacembelus armatus* became extinct, *Labeo rohita* depleted from average annual 2.19% to 0.2%, *Cirrhinus mrigala* 6.32% to 0.3%, *Labeo gonius* decreased from 8.82% to 0.54%, *Puntius sarana* 7.92% to 0.25%, *Wallago attu* 3.56% to 0.71%, *Mystus spp* 7.20% to 1.10%, *Notopterus notopterus* 2.44% - 0.01%. The weed fishes were increased tremendously from 53.4% to 96.41%. Indian major carps immediately rehabilitated due to stock enhancement programme, while other fishes were re-entered through inflow. As a result of drying phenomenon *Labeo calbasu* and *Nandus nandus* became scarce possibly due to their absence in incoming waters.

B. Discussion

Fish yield in impoundment depends not only on geomorpho-bio-chemical characters but much more on manner and level of exploitation.As the base of Pahunj reservoir is flat and devoid of obstructions such as trees, boulders and bushes, it facilitate the use of all kinds of gears and nets. During maximum water level the deeper portions of main reservoir are exploited by gill nets and purseseine nets while drag net and mahajal are common in shallow areas. Trapes are used in shore areas. Yields from this reservoir shows definite pattern. After achieving a particular level it slide down after 2-3 years. An average yield was obtained (43.57 kg/ha) during royalty system with a significant difference in lower and upper limits. Analysis of catch efforts reveals that intensity of net operation and efficiency increased gradually in subsequent years. This irrational exploitation was inconsistent to the available stock because efforts in terms of men/day was 24 in 1976-77 when catch per man was 700.91 kg fish. This maximum yield in terms of per man efforts was recorded when only 14 fishermen were employed which is near to f_{msy} (11 men/day). The maximum boat operated in this reservoir was 68 (1972-73) and achieved 247.94 kg/boat. The maximum yield/boat was 3998.2 kg in 1977-78 at 5 boat/day only. The net operated per day were only 25 in 1970-71 when fish yield/net was 1145.24 kg. The increase in intensity of net/day upto 2100 net decreased the per net production to 10.659 kg. It reflects the over exploitation of fish stock. It is evident that fish yield in relation to fishing stress get established at a specific level but declined after a certain interval due to unbearable stress.

During outright auction, with quota system, the productivity was almost constant due to restriction on fish catch at 17.0 t/annum level with 29.0 kg/ha average. After 1995 the fish yield increased gradually due to restriction free system under world bank scheme. It increased from 29.18 to 142.65 kg in 1997-98. Such a quantum enhanced yield was possible due to improved management policies. In preceding years approximately 0.2 million fry of about 10 to 15 mm size were usually stocked. But under World bank scheme about 0.4 million fingerlings of a larger size (10-15 cm) were stocked .

Fish catch structure is a manifestation of respective fish stock and its exploitation. The 'A'

and 'B' category fish together which represents Indian major carps behaved as sub population. It fluctuated from 0.22% to 37.6% according to their recruitment and mortality. This group is economically significant and biologically susceptible due to short food chain and better conversion efficiency. It is always prime victim of over exploitation. Although the supplementary stocking have been done every year but level of exploitation is also non desirable. The major carps were 8% in 1965-66 and varied between 5.8% (1969-70) - 12.5% (1971-72). Their percentage declined to 1.46% in 1972-73 and established at 6.35% in next year (1973-74) and 16.23% in 1974-75. It increased to 37.6% in 1976-77 as reservoir was stocked 801 fingerlings/ha (1972-73), 439/ha 1973-74 and 403/ha (1975-76). In 1978-79 they again became scare (6.07%).

It is clear from above discussion that major carps substantially contributed in certain years in alternate fashion. Probably this is due to excessive fishing pressure on major carps. Contractor made efforts to catch maximum major carps effects the breeding and recruitment of fishes in the reservoir resulting their depleted stock in subsequent years. Restriction on fishing of less than 1.5 kg fish support their population growth in next year.

During ten year stretch of 1984 to 94 the quota of major carps to be netted out was 12.5% of total catch (17.0 t). These limits were followed so the major carps contributed about 12.56% and 12.05% in 1989-90 and 1990-91 respectively.However, it was increased to 35.5% in 1991-92 and stipulated to 26.38% (1992-93) and 29.87% (93-94). The increase in the major carp ratio was due to stocking of Indian major carps seed by the contractor. Category 'A' contributed only 0.5% in 1995-96 due to over fishing during scarcity of water in June 1995-96. Stocking of 4 lac fingerlings of 10-15 cm size after rearing in a pen this category got a boost and attained 43.65% in 1997-98.

The 'C' Category fishes which include economically valuable catfishes, such as murrels, feather back and bams represented 44% in 1965-66 and declined to 13.58% in 1970-71. But again they exhibited inclining trend and reached 43.11% in 1974-75 and 68.87% in 78-79. During outright auction period (1985-95) their annual contribution was 31.90%. After desiccation in 95-96 which adversely effected the bottom fauna also, they dropped down to 9.25% level and

gradually increased in coming years. Table (25,26) and Figure (37,38) shows that weed and carnivores fishes were less while the major carps were abundant.

In 1978-79 department has allowed the weed fish net for the first time so that weed fishes which act as forage fish to carnivores (Category 'C' fish)get disturbed. It might exert negative effect on carnivore fishes. The food chain was disturbed and left plenty food for major carps. Hence the major carp contributed at 30.0% in this year and category 'c' fishes declined to 68.97% to 6.07%, in next year 1980-81. The 'C' category fishes increase to 35% and major carp was 0.22%, while forage fishes (weed fishes) increase to 48.65% in catch. It may be due to the fact that in case of depletion of forage fish the predatory fishes might have started to pray on major carp seedlings so that the contribution of major carp declined and cat fishes increased to 35%. Because contractor always operate hook and lines in reservoir. These category 'C' fish remain at low level. Hence there is a definite correlation between these three population.

The category 'D' fishes include *Labeo gonius, Puntius spp, Chanda spp, Glossogobius guirius, Oxygestor buchaila, Nandus nandus, Anabas testeudeneus* and other juveniles of 'C' category fishes. These fish compete with the major carps primarily for food and secondarily for space but provide forage to carnivores fishes. These were maximum (77.03%) in 1970-71 and 96.51% in 1995-96. During 1984-95 periods they varied between 33.81% (89-90) - 58-81% (1994-95) and followed a close relationship with category 'A' and 'C'.

It was noticed that the minor carp fishery is some what depends on other type of fishes. When their number is more, major carp were less. This situation sustains carnivores at high level. When weed fishes occur at low level the cat fishes were also less. When the weed fishes increased to 49.8% (1966-67) to 63.02 (1968-69), the major carps decline slightly from 10.22% (1966-67) to 6.42% (1968-69). However cat fishes were declined sharply from 45% (1966-67) to 29.77% (1968-69). The minor carps were maximum in 1970-71 while major carps were only 9.17% and cat fishes 13.58%. The weed fishes were at lower level with 24.96% during 1978-79 whereas the catfishes were at highest with 18.97%. The major carps were at higher level with 37.6%, 30.42% and 30.01% in 1976-77, 1977-78 and 1979-80 respectively whereas both cat fishes and

minor carps /weed fishes were 24.9% and 37.5%, 39.15% and 30.43%, 15.77% and 4.7% respectively in corresponding years.

The species composition for all three lease system were analysed taking random sample years for all the auction systems. The commercial species were also grouped into feeding categories i.e. planktivores, omnivores, second level carnivores (SLC) and third level carnivores (TLC). The planktivores are represented by only one species namely *Catla catla*. Numerically their share was 1.05% in 1971-72 to 4.8% in 1976-77, 1.57% to 5.49% between 1989-92, Nil to 14.63% during 1995-98. *Catla catla* has no competitor for food but it seems that due to low recruitment and easy catch it remains under certain limits. The omnivores comprises *Labeo rohita, Cirrhinus mrigala, Labeo gonius, Puntius sarana, Labeo calbasu* and other carps and weed fishes. The omnivores were 54.79% in 1971-72 and increased steadily to 70.75% in 1976-77 and around 80% in 89-91. These shows slight decline with 73.41% in 1991-92. In 1995 they contribute about 97.45% in the total fish catch. The average for ten years is 75.48%. Among omnivores the *Labeo rohita, Cirrhinus mrigala, Puntius sarana* and *Labeo gonius* show remarkable variation in their abundance. The *Labeo rohita* was 2.41% in 1971-72, increased slightly to 4.90% in 1974-75 and reached 20.75% in 1976-77. It implies that over exploitation in 1971-72 to 1975-76 kept this species at low level but in 1975-76 the fishing was closed for most of the year except in May and June' 75. Hence *Labeo rohita* reappeared in 1976-77 with 20.75% of total catch. During 1989-92 *Labeo rohita* ranged only between 1.24% (1990-91) to 3.03% (1989-90). After water scarcity in June'95 it became almost extinct and contributed only 0.20% and 0.41% in 95-96 and 96-97 respectively. It reappeared only when reservoir stocked large sized seed and made 21.58% of total catch in 1997-98 and was ever highest recorded Rohu biomass of 15,766.78 kg in last thirty years.

Second level carnivore comprises *Mystus spp, Ompok pabda, Notopterus notopterus* and *Mastacembelus armatus* and was 27.0% in 1971-72, declined to 17.83% in 1975-76. the SLC dwelled between 10.67% (1990-91) to 16.00% (91-92) and 5.10% to 10.45% during 1995-98. Among SLC the dominant group was *Mystus spp* and *Notopterus notopterus*. The *Mystus spp*

was 12.19% in 1971-72, increased to 18.85% in 1974-75. and declined to 4.39% in 1976-77. In 1989-91 it varied between 1.74% (1990-91) and 2.42% (1989-90) after June'95 it appeared with only 1.1% and increased to 5.73% in 1996-97, while decreased to 3.94% in 1997-98. The *Notopterus notopterus* was 13.63% in 1971-72 declined to 0.17% in 1974-75 and increased to 17.65% in 1975-76. It was only 7.12% during 1976-77 in the catches. During 1989-91 it contributed only an average 7.0% and less than 1.0% between 1995 to 1997-98. Hence *Mystus spp* and Notopterus shows alternate dominance over each other.

The third level carnivores (TLC) comprises *Channa spp* and *wallago attu* only. They were 17.16% in 1971-72 decreased to 14.51% in 1974-75 and varied between, 4.39% (76-77) and 5.50% (75-76) show declining trend due to high demand and high prices in the market under over exploitation by hook and line fishing. This good sign for the proliferation of planktivores and omnivores. During 1989-92 the TLC varied between 2.73% to 6.23% .After 1995 the TLC contributed only 0.18%(95-96), 0.50% (97-98). Among TLC *Channa spp* always made low contribution than the *Wallago attu*.

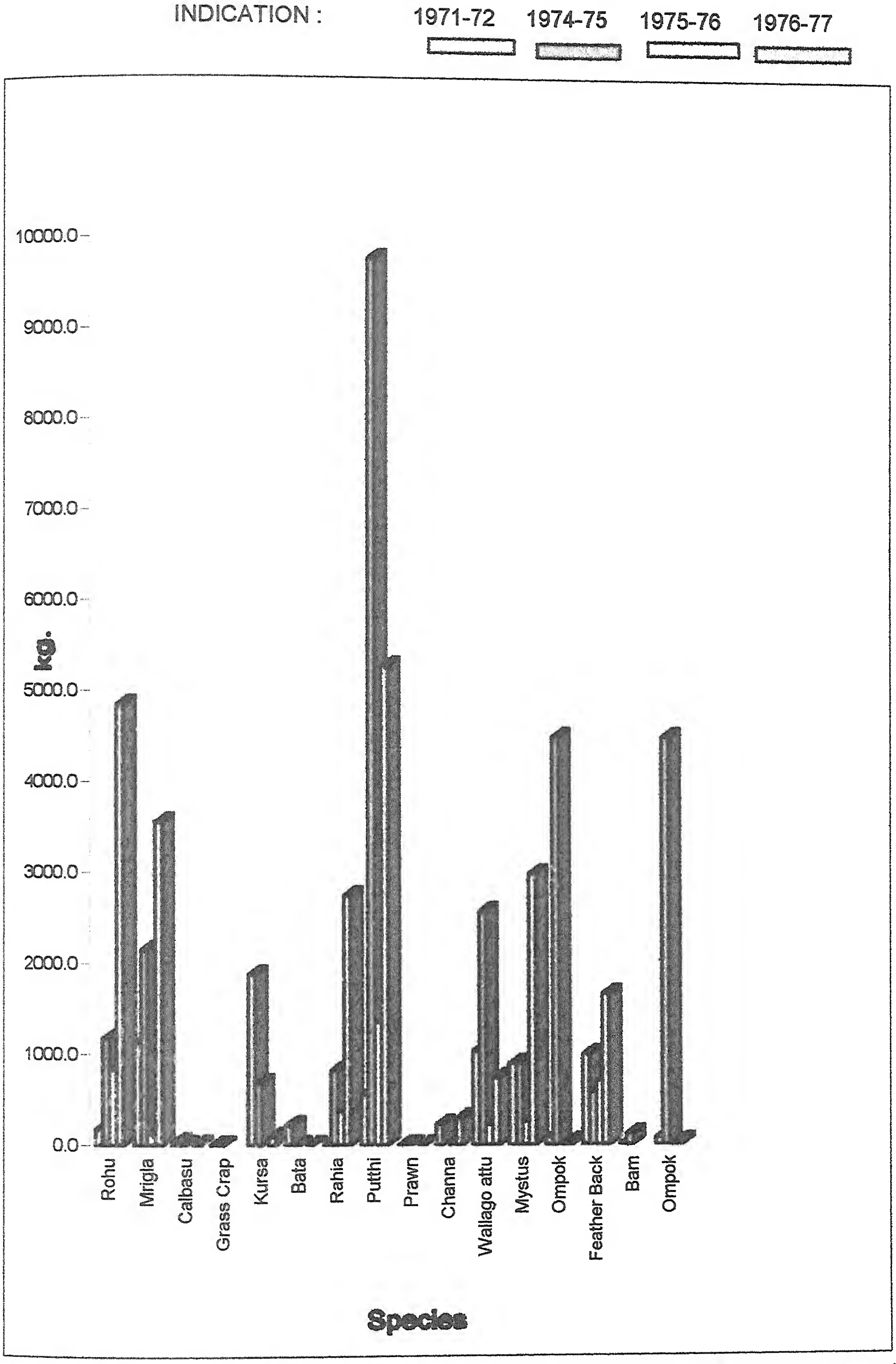


FIGURE-33 : Comparative species composition in Pahunj reservoir (Royalty auction system)

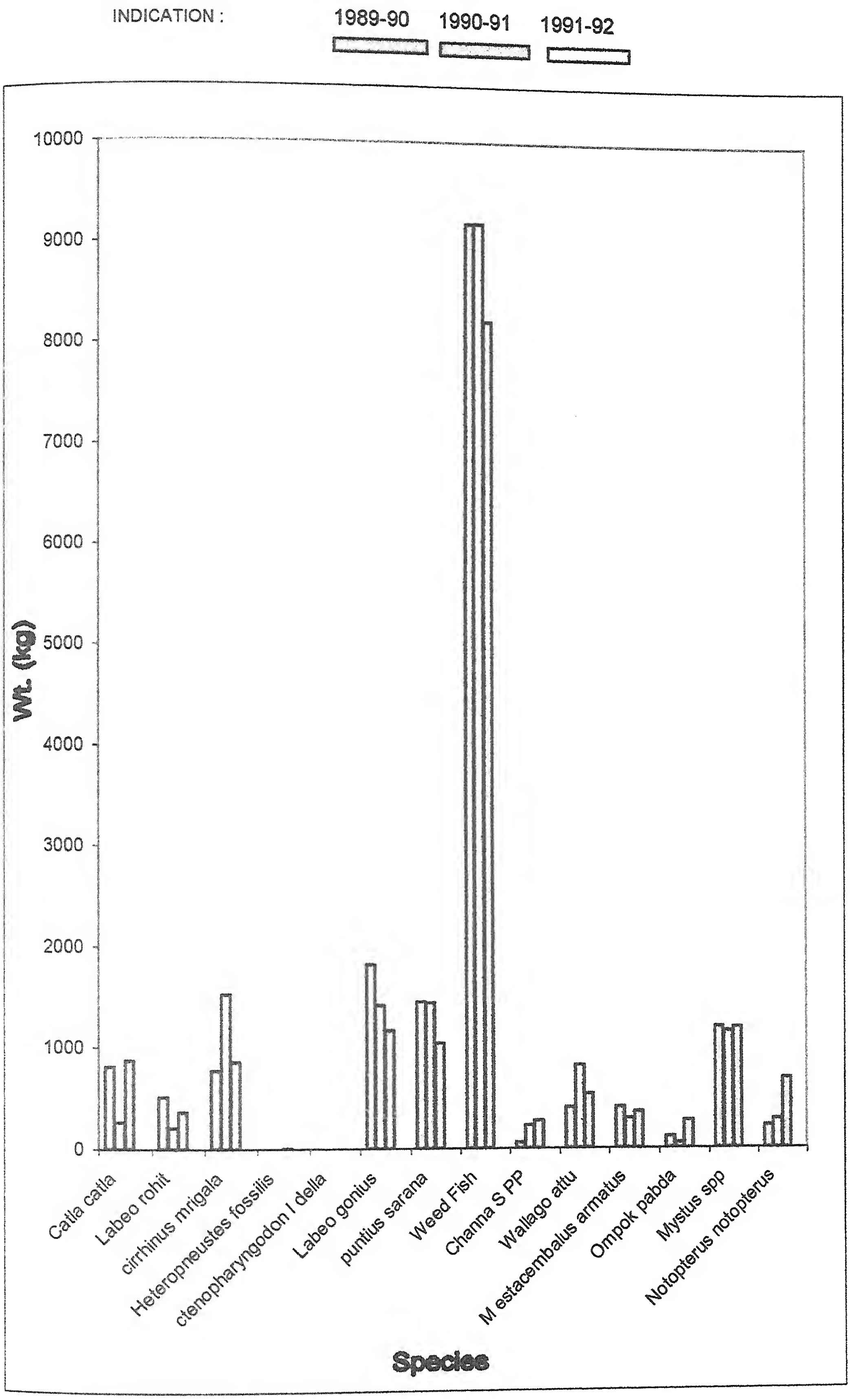


FIGURE-34 : Comparative species composition in Pahunj reservoir.
(Out-right auction with quota system)

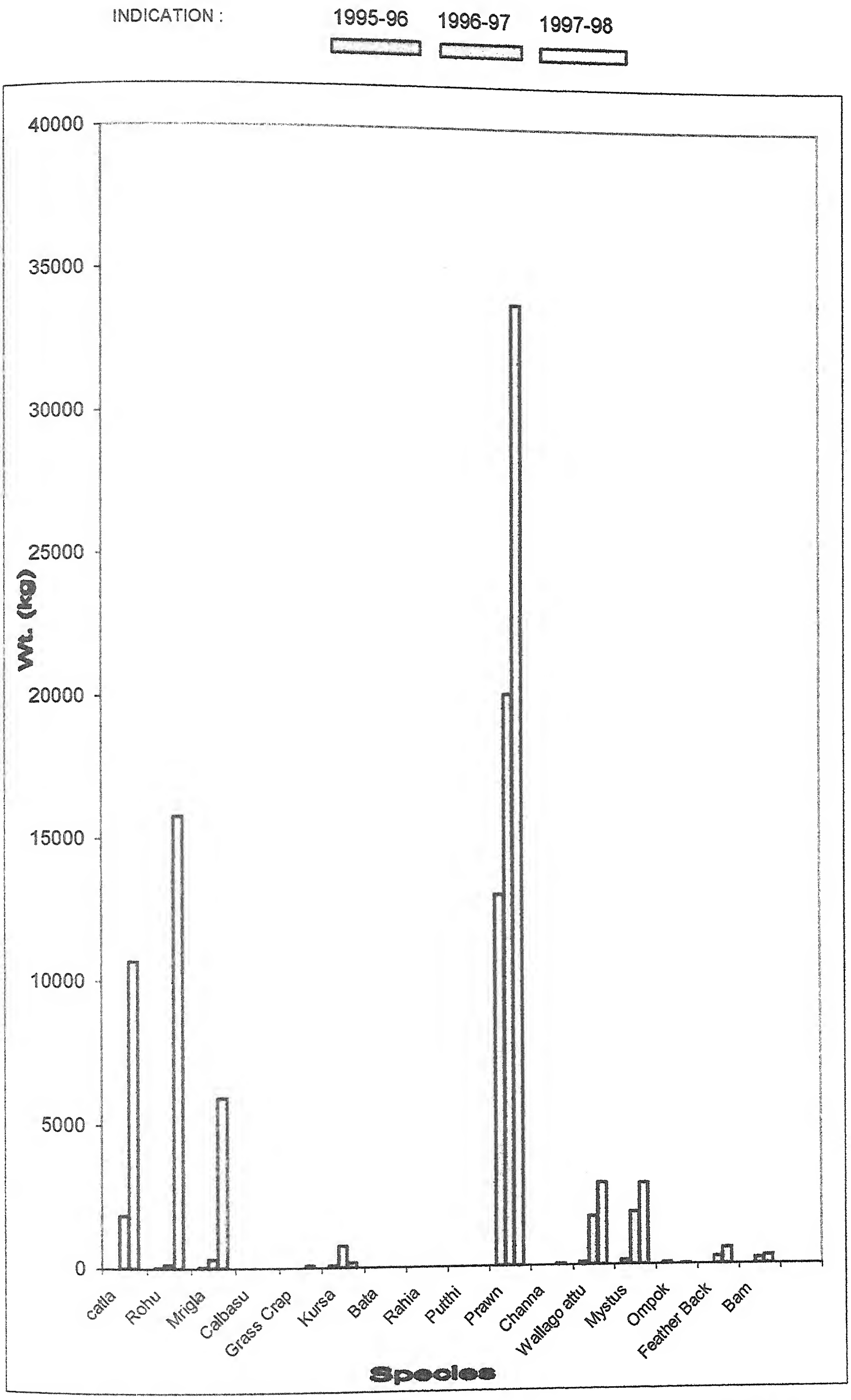


FIGURE-35 : Comparative species composition in Pahunj reservoir of year 1995-96, 1996-97 and 1997-98. (Out-right auction with quota free system)

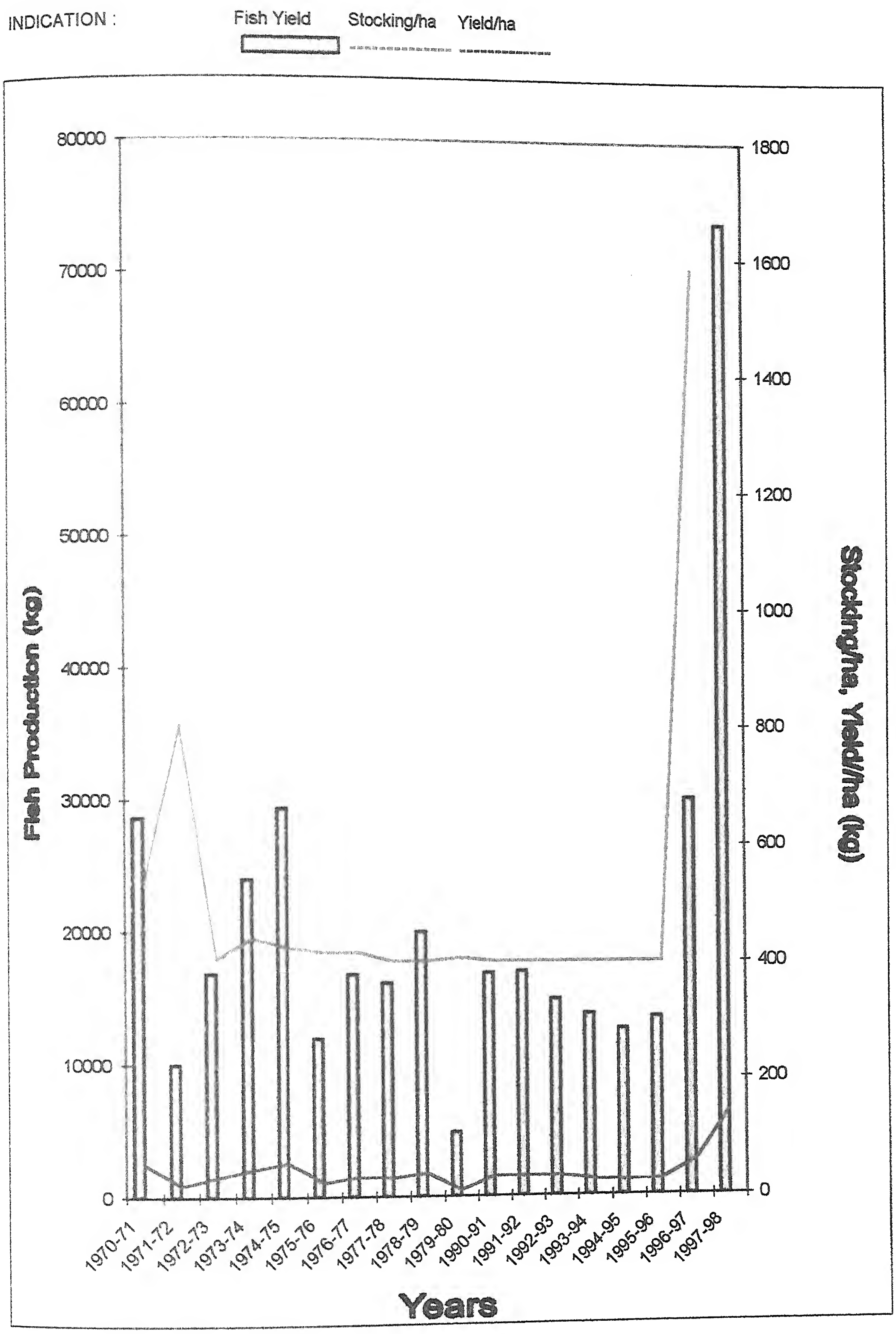


FIGURE-36 : Yearly fish production fish productivity (kg/ha) along with stocking rate .

INDICATION : Category A , B C D

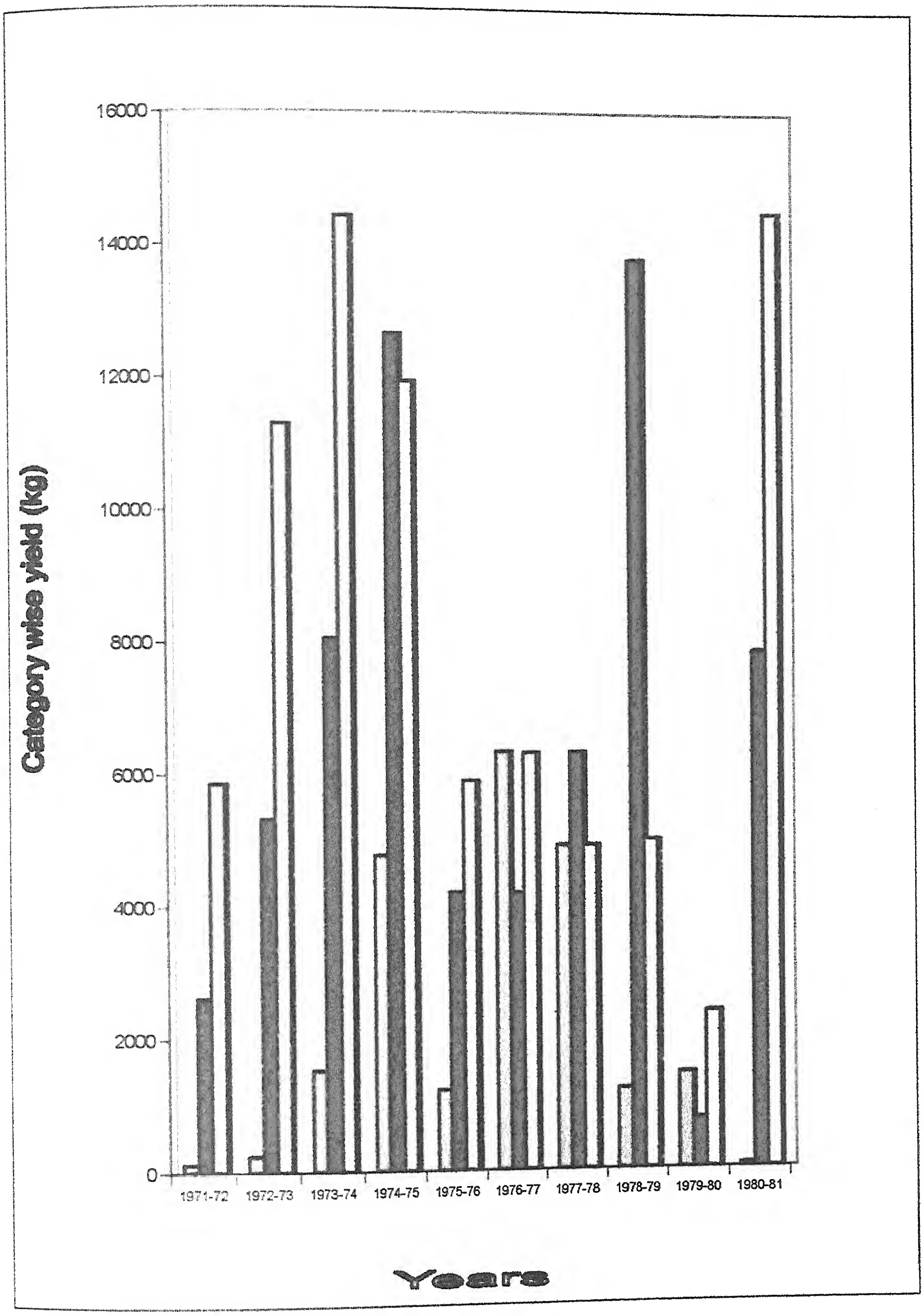


FIGURE-37 : Category wise fish production in Pahunj reservoir. (Royalty system)

INDICATION : CATEGORY A, B C D

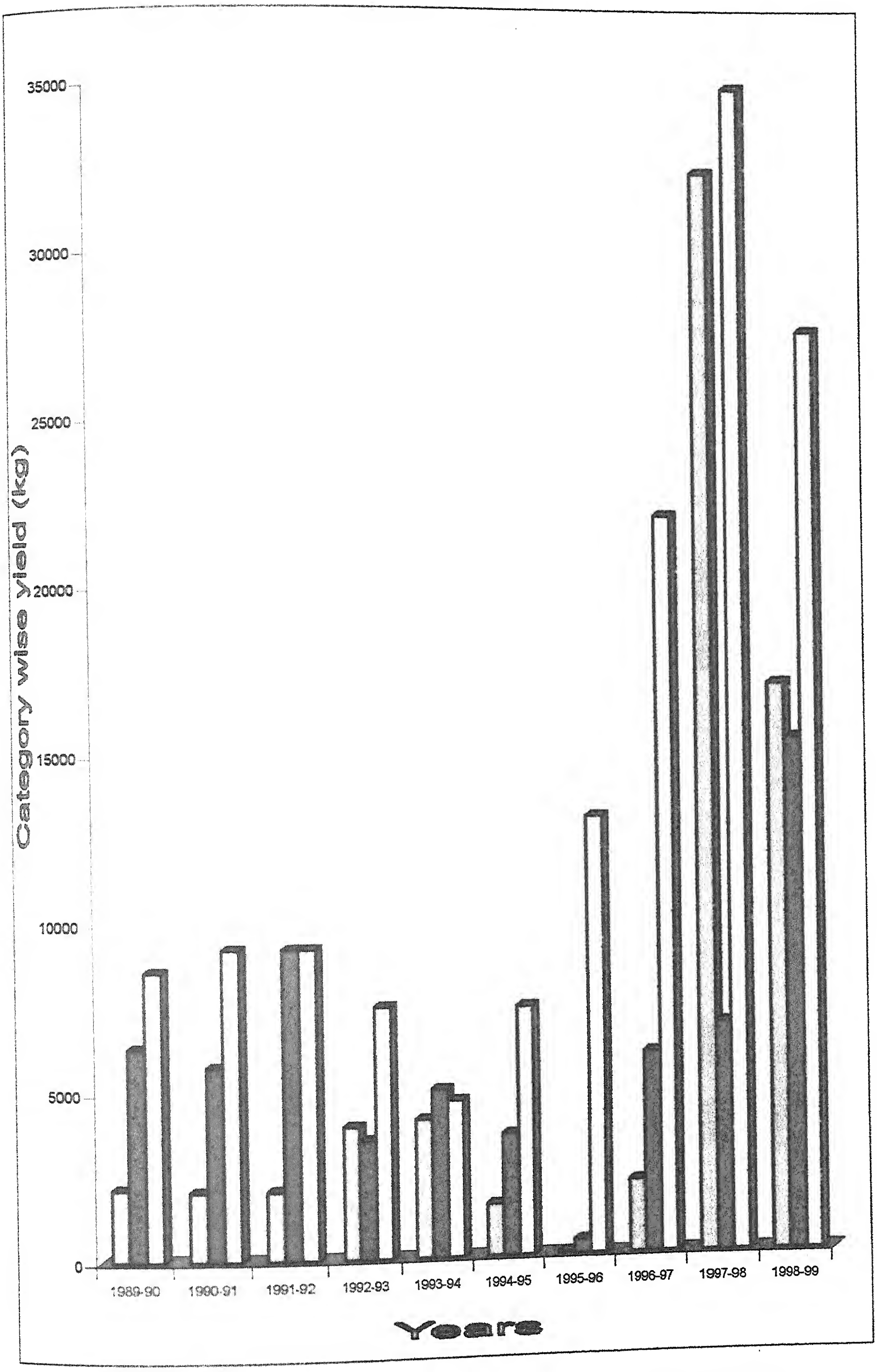


FIGURE-38 : Category wise fish production in Pahunj reservoir. (Out-right auction system)

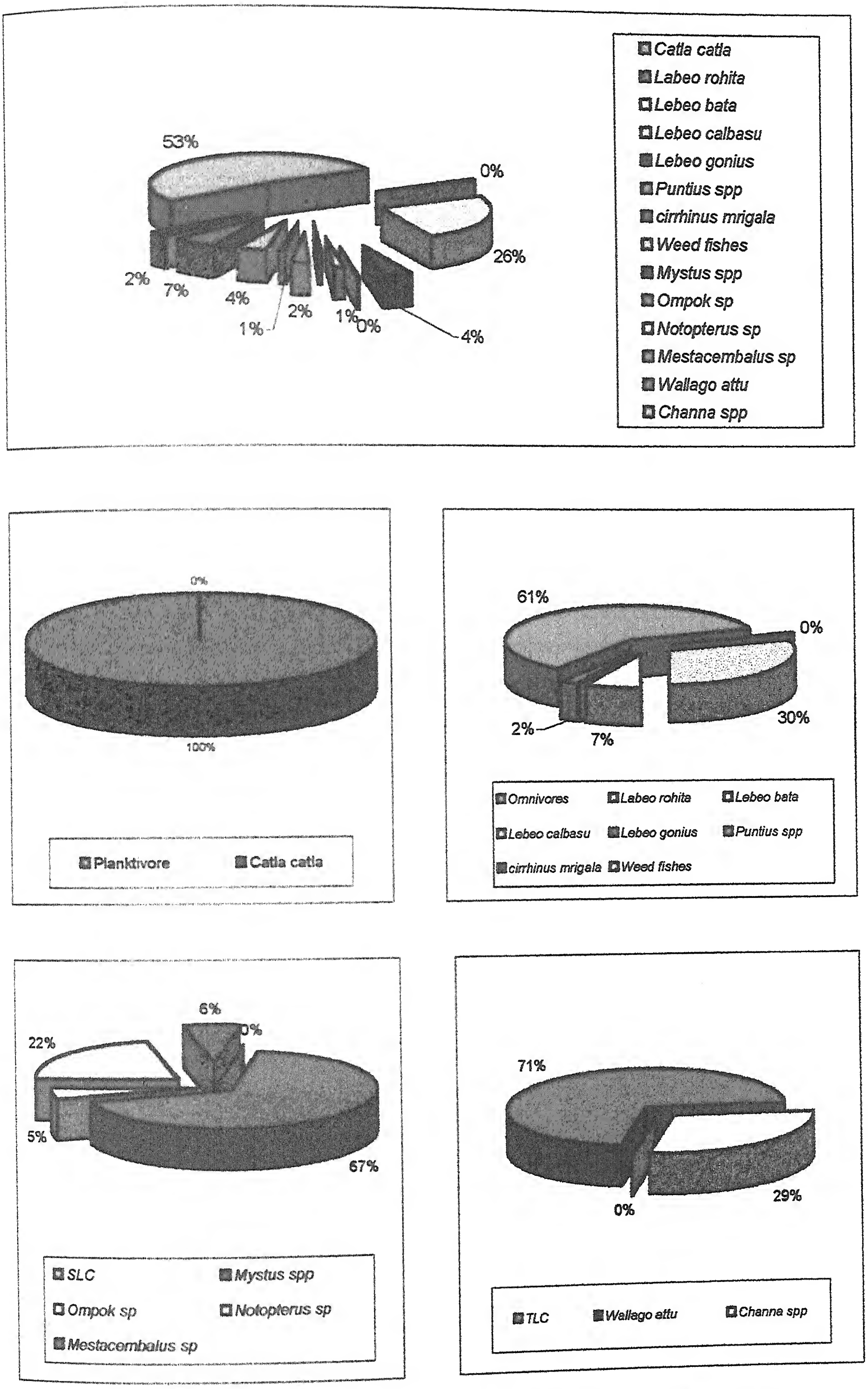


FIGURE- 39 : Feeding category wise catch composition on the basis of year 1971-72, 1974-75 to 1976-77, 1989-90 to 1991-92 and 1995-96 to 1997-98

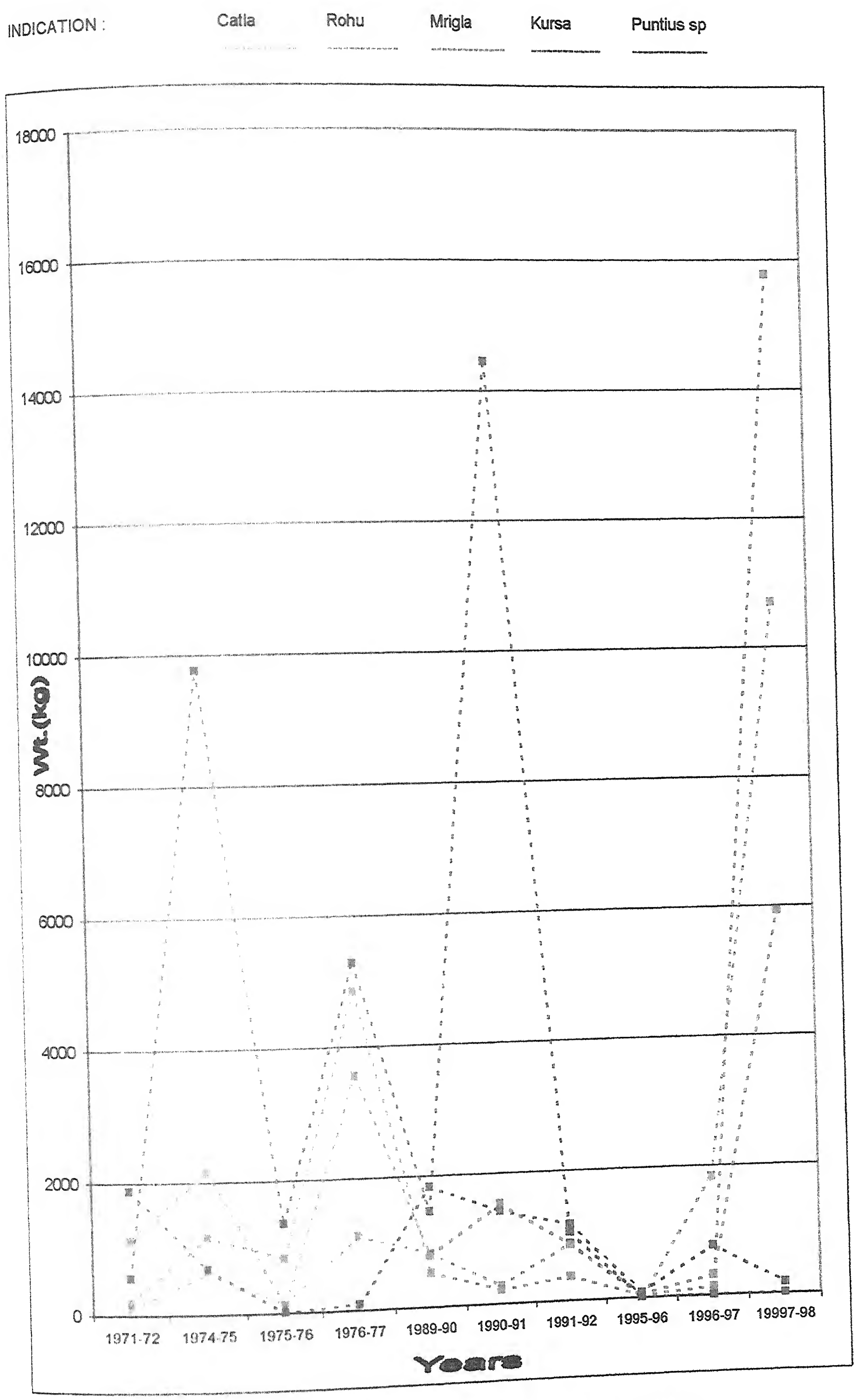


FIGURE-40 : Species dynamics of Planktivore and Omnivores feeding category .

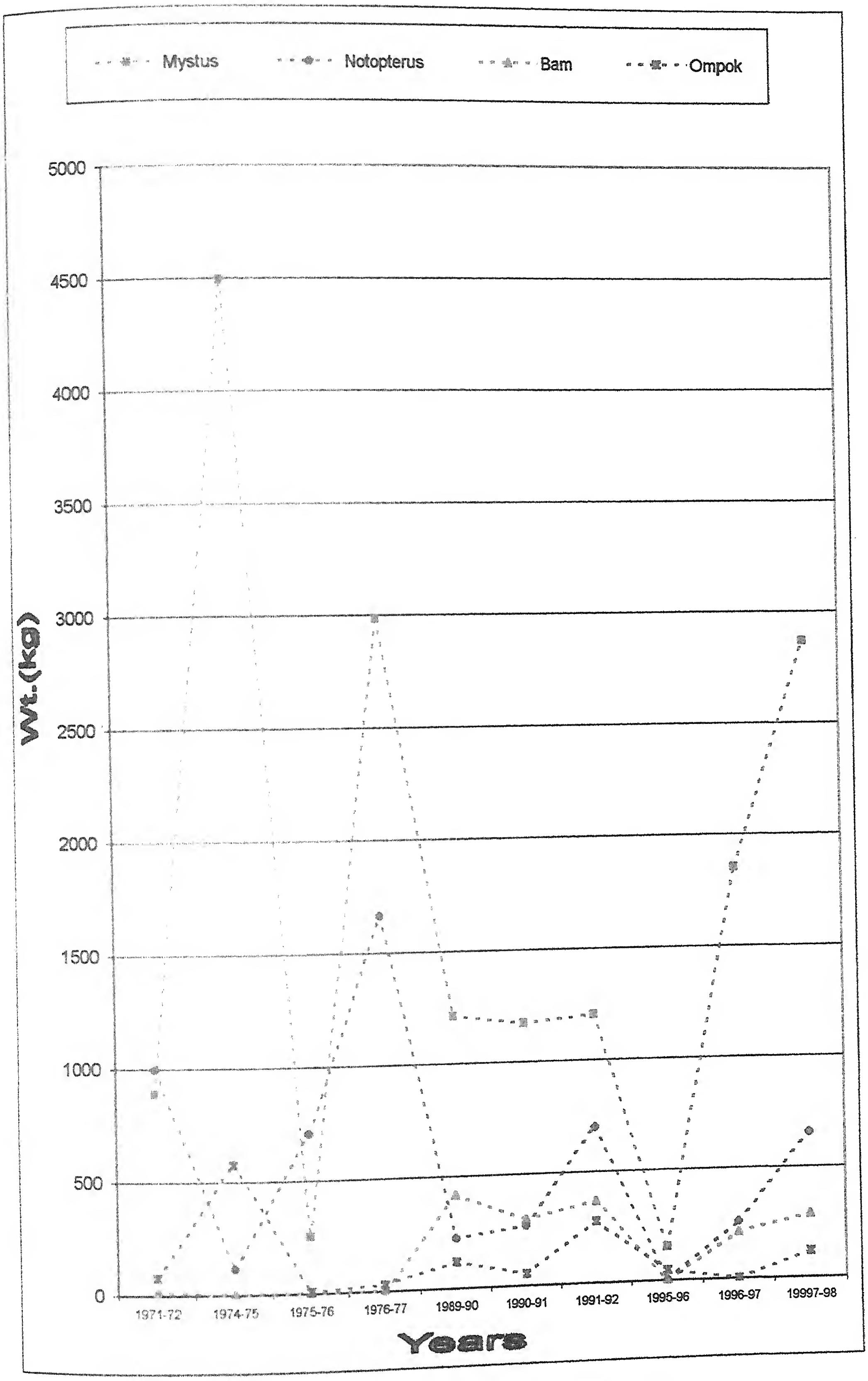


FIGURE-41 : Species dynamics of Second level Carnivore feeding category .

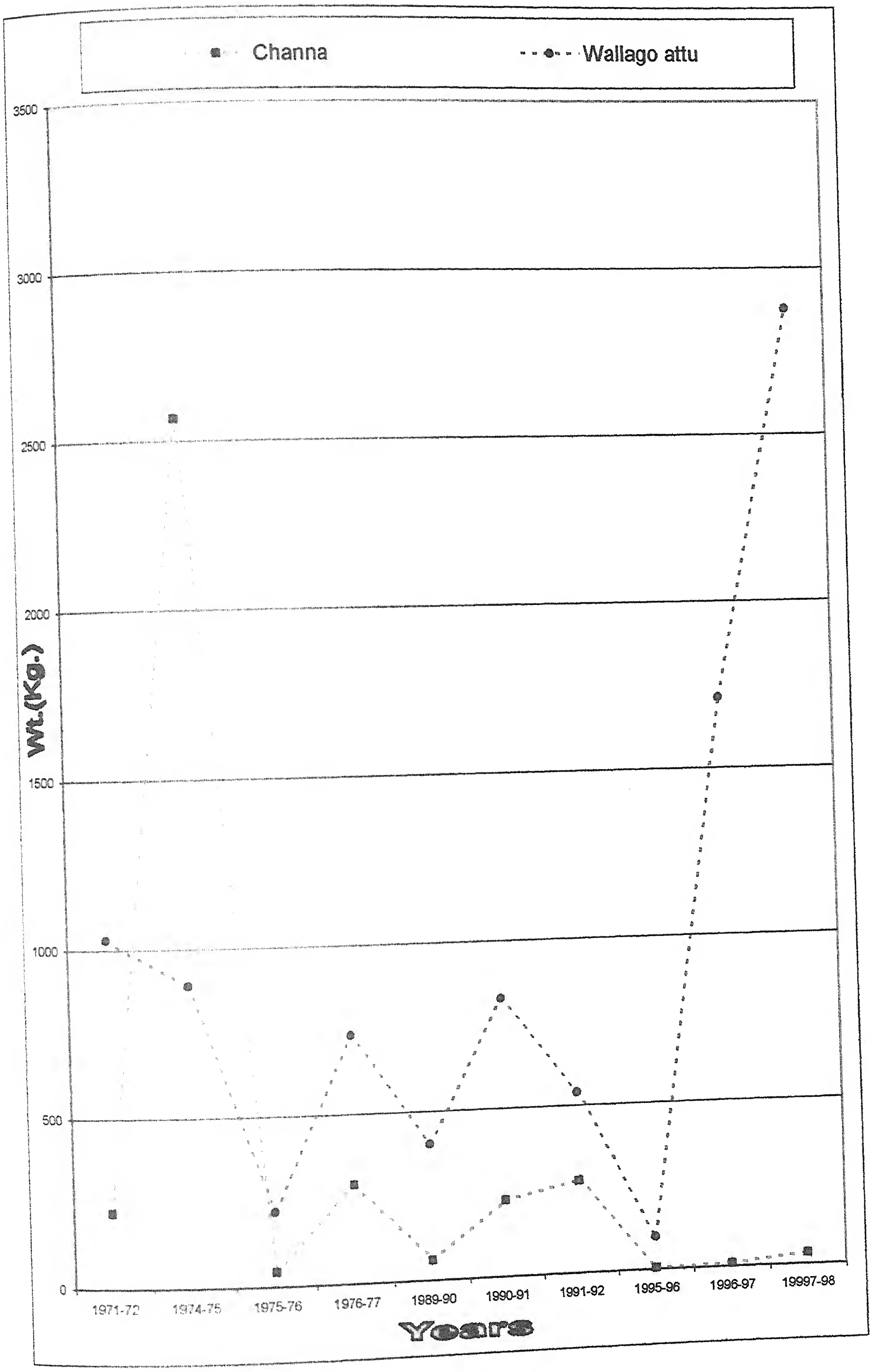


FIGURE-42 : Species dynamics of Third level Carnivore feeding category .

Chapter -9

Summary

1. Pahunj reservoir was constructed on Pahunj river at Simardha village 9 km away from Jhansi city in the year 1910 as a multipurpose reservoir for supply of drinking water and irrigation. It has water area for 518 ha at FRL.
2. Yearly water inflow in the reservoir varied from 308.991 Mcft (1994-95) to 90938.342 Mcft (1994-95). Water inflow depends on rainfall.
3. Meteorological data were obtained from Indian Grass and Fodder Research Institute Jhansi. The average rainfall is 802.64 mm with minimum 566.9 mm (1994-95) and maximum 990.8 mm (1990-91). The average wind velocity was 4.51 km/hr with minimum value of 2.78 km/hr (1995-96) and maximum 6.30 km/hr (1990-91). The average annual evaporation rate was 5.7 mm/day with minimum 2.0 mm/day (Dec'91, Dec'93 and Jan'93) and maximum 13.9 mm/day (May'96).
4. The maximum temperature of air (48.5^{0}c) and minimum (4.0^{0}c) was observed in June'95 and Jan'96. The maximum water temperature (36.0^{0}c) and minimum (8.5^{0}c) was observed in June'95 and Jan'96.
5. Water quality of the reservoir is rich with respect of PO_4^- and NO_3^-. Reservoir shows average total alkalinity over 100 mg/l and therefore, may be categorised as highly productive. (sugnan and Jhingran, 1990).
6. Free CO_2 was always present in the reservoir in morning time which attributed to respiratory activities in the night. Therefore, CO_2 was never a limiting factor for the photosynthesis in the morning hours. However, it becomes nil at 2 pm and happens to be a limiting factor.
7. The minimum dissolved oxygen was always above 1.8 mg/l in the morning hours however low values might be causing slight stress for fish fauna. The highest value was recorded 9.2 mg/l in Nov/Dec'95. This reservoir has never shown the super saturation with oxygen. The equilibrium between respiration and oxygen production was observed in this reservoir.
8. pH remain always towards alkaline side. The maximum value 9.2 recorded at 2 pm (Dec'95). When rate of photosynthesis rate was at maximum, shows equilibrium well with alkalinity, Free carbondioxide and dissolve solids.

9. The average GPP, was 1.507 gC/day and NPP was 1.145 mgC/day, which is 75.94% of GPP. It is very high in comparison to reported earlier. It is approximately 40% in Rihand. The annual gross GPP is to be 2850.98 t carbon and annual NPP is to be 2165.154 t carbon.

10. Phytoplankton were largely contributed by *microcystis*, *Coelospharium* and *Phacus*. Zooplankton are represented by copepod, Cladocerans and Rotifers. The phytoplankton population was highest in May- June and November-December and lowest in monsoon season (Aug-Sept) and regulated by silt clay and free carbondioxide content in flowing water during monsoons, temperature and concentration of nutrients in rest of the period.

11. Periphyton is scare during monsoon owing to water turbulence but appear during post monsoon month when reservoir is calm. These are represented by *Oscillatoria* and their abundance coincide with the plankton.

12. Aquatic plants do occur in october and November. They increased towards the April due to high temperature, causing trouble in fishing operation some times.

13. Survey of fish fauna establishes the presence of 37 species belonging to 22 genera and 12 families in this reservoir.

14. Fish yield/ha in reservoir progressively decreased up to 1994-95 from 92.39 kg/ha in 1965 to 43.29 in 1980-81 gave the average of 43.54 kg/ha. Fish yield from 1981-82 to 1995-96 remained stable and varied between 29 kg/ha - 30 kg/ha during fishing year 1995-96. The fish production/ha improved from 26.07 kg/ha (1995-96) to 140.60 kg/ha (1997-98).

15. Contribution of Indian major carps (Category 'A') in total catch was 12.40% (1965 to 1980-81) with minimum 0.22% in 1980-81 and maximum 37.6% in 1977-78. The predatory fishes contributed average 37.0% with minimum 15.77% (1979-80) and maximum 68.97% (1978-79). The minor carps and other miscellaneous weed fishes contributed an average 50.1% with minimum 24.96% (1979-80) and maximum 77.03% (1970-71).

16. Indian major carps (category 'A') improved during 1989-90 to 1993-94 from 12.56% in 1989-90 to 29.87% in 1994-95 but declined to 0.50% in 1995-96, reappears and increased to 43.65% (1997-98), the overall average was 17.4%. The category 'C' fishes contributed an

average of 22.39% with minimum 2.99% (1995-96) and maximum 36.32% in 1993-94.

17. The minor carps and other miscellaneous fishes (category 'D') contributed on an average 57.51% with minimum 33.81% (1993-94) and maximum 96.51% (1995-96).

18. Species composition for preceding 10 years was randomly worked out . The average composition is found to be *Catla catla* 7.34% (0-14.63%), *Labeo rohita* 10.75% (0.2-21.58%), *Cirrhinus mrigala* 7.32% (0.3-15.34%), *Labeo calbasu* 0.21% (0-0.44%), *Labeo bata* 0.09% (0-40.49%), *Wallago attu* 15.17% (0.7-17.16%), *Channa* spp 1.67% (0.03-10.77%), *Mastacembelus armatus* 0.7% (0-4.4%), *Mystus* spp 7.64% (1.1-18.85%), *Ompok pabda* 0.53% (0-2.41%), *Notopterus notopterus* 8.3% (0.01-17.65%), *Puntius sarana* 9.35% (0-40.49%) and other miscellaneous species 44.35% (0.41-96.41%).

19. The feeding categories wise composition was planktivore 7.3%, omnivores 75.48%, third level carnivore 5.84% and second level carnivore 11.34%.

20. The maximum sustainable yield (MSY) found to be 33.101 t/annum at the maximum effort (f_{msy}) 11 men/day. There is wide gap between average exploitation level 14.623 t per annum for 18 men/day and msy of 33.101 t for 14 men/day.

21. On the basis of net primary production (1.145 gC/m²/day) the fish biomass estimated to be 161.737 t which represent the productivity of 312.33 kg/ha and shows 9.9% conversion from primary production to fish biomass.

22. The average fish seed stocking from 1965-66 to 1980-81 found to be 540 fingerlings/ha and 400 fry/ha from 1981-82 to 1995-96.

Chapter -10

Recommendations for Management

- ☆ The MSY has been estimated to be 33.101 t for the f_{msy} of 11 men/day and 20-22 boat and approximately 400 gill net/day or two "facy" pursein unit or two "Chatti Party" only at a time. The average annual production 14.623 t for 14 men/day , 30 boat/day or net day. Evidently there is a wide gap between the present level of exploitation 14.623 t for 14 men/ day the MSY of 33.101 t. Therefore, it is desirable to reduce the efforts to 11 men/day, 20-22 boat/day and 400 nets/day, two facy party, two chatti party to achieve the designated optimum annual yield of 33.101 t on long term basis.
- ☆ The MEY has been estimated to be 30.377 t for f_{mey} of 10 men/day. Therefore, not more than 10 men/day should be employed if profit maximisation is the basic objective of the fishery.
- ☆ According to trophodynamics model of Malack (1976) the productivity estimated to be 27.56 kg/ha while reservoir has already shown 43.57 kg/ha (1965-66 to 1980-81) and 142.648 kg/ha in 1996-97. As this level was achieved by stocking large sized fingerlings, there is a need to redefine the stocking policy.
- ☆ On the basis of primary production the fish biomass in this reservoir, which can carry, is estimated to be 161.737 t. It is higher than estimated by surplus model 66.202 t (double of MSY). The carrying capacity of 161.737 t fish represent 9.99% conversion ratio from primary production to fish biomass. Such a higher fish production can be sustained by applying the fish seed stocking formula described by Huet (1960) i.e stocking ratio = Gross total production in kg / Individual growth in kg + % loss. By assuming that we would allow 60% of Indian major carp and 40% of SLC, TLC and other omnivore to preserve biodiversity at 50% mortality rate and 1 kg average growth. The stocking for Indian major carp should be 1.94 million or 375 fingerlings/ha/annum. The ratio of Catla, Rohu and Mrigala is to be 30:40:30. Implant of grass carp to arrest the weed infestation and common carp to use the bottom fauna and flora, the stocking ratio should be 30% Catla, 30% Rohu, 10% Grass carp, 20% Mrigala and 10% common carp. At this rate the Catla 113/ ha, Rohu 113/ha, Mrigala 74/ha grass carp and common carp 38/ha, each can be stocked.
- ☆ Fisheries department establishes the pen of 0.2 ha for rearing the fish fry upto two months to

obtain 10-15 cm fingerling of major carp for stocking in reservoir. The result was very encouraging and should be continue in future also.

- *Catla catla* is the only planktivore and contributed 7.43% (Nil - 14.63%) in catches which is very low. Perhaps, this situation indicates that this species is overexploited. So there is a need to stock the reservoir with 113 fingerlings/ha of this species to utilize surface productivity fully.
- *Labeo rohita* was 2.41% in 1971-72 and contributed 20.75% in 1976-77 but declined in subsequent years after 1990. Hence there in need to stock the reservoir with 113 fingerlings/ annum to supplement native stock.
- *Cirrhinus mrigala* contributed from 0.3% to 15.34% in different years. It is an abnormal variation. Hence the reservoir should be stocked with 74 fingerlings/ha every year for regularisation of this species.
- *Labeo calbasu* (Karounch) which was present during 1971-72 to 76-77 disappeared after 1995. It indicates that the reservoir can harbour this species but due to depletion of brood stock it disappeared. Karounch is a commercially important carp which feed on vegetable, debris, microscopic plants and bottom feeder, can utilize bottom niche efficiently, should also be revived.
- *Labeo gorius* declined 0.23% from 25.71% (1971-72). This is a bottom column feeder herbivore. To establish this species some effort has to be made.
- *Labeo bata* was present 2.88% in 1971-72 and made small contribution upto 1990-91 but disappeared after water scarcity in June' 95. It is a detrius feeder and bottom dweller hence this species also needs some rehabilitation.
- Second level carnivores (*Mystus spp, Notoperus, Heteropneustus fossilis, Clarius batruchus* etc.) made 5.10% to 27%. Because of their economic importance and biological importance (in converting secondary biomass to tertiary biomass) second level carnivores like *Ompok spp, Mystus aor* and *Mystus seenghala and Pangassius pangassius* population should be

preserved every year to supplement their stock.

- ☆ The TLC population is very low in reservoir. This situation is very congenial for the proliferation of major carps and other carps so as to maintain status quo, the hookline should be operated every year for their efficient exploitation.
- ☆ Weeds like *Hydrilla, Ceratophyllum, Lemna and wolffia* grow after November. Sometime there number increases to 3800/m² in periphery of reservoir which create hindrance in fishing operations. Moreover it drain essential nutrient from reservoir water. To utilize and check it the grass carp should be stocked at the rate of 38 fingerling/ha.
- ☆ Heavy demand for water due to late rains in June'95 compelled almost complete draining of reservoir. This adversity resulted in the loss of water to almost 2-3 ha area with 1-1.5 m depth. This situation was havoc to fishery and lead to complete extinction of some species. Hence there is a need of definite water use policy so that the minimal water level never go below dead storage level (DSL). Concerned department should formulate a need based policy to avoid such situation for the survival of aquatic fauna..
- ☆ At present the department has adopted out right auction system for exploitation of fisheries, and auction is made among co-operative societies. As it is well know that coperative societies are financially weak but open auction system forces these coperative societies to bids more and more. They borrow money from money lenders and the basic aim for social upliftment of fishermen community is by passed. In this regard the system of Himanchal pradesh (Pong dam) and Rajasthan (Jai Samand lake) can be adopted after due consideration. Where the local society members are trained in fishing and are given license. They carry their per day fish catch to fishery officials and per unit labour cost according to fish catch is paid to fisherman. The whole catch is collected and this is lifted by a contractor. For fish lifting rate are fixed on the basis of open bid/tender time to time only a part of income, fisheries department keeps as a administrative royalty and surplus is divided among the society members in the ratio of their contribution.
- ☆ At present UP Fisheries Act 1948 is enforced for the conservation and management of fishery.

The close season is observed from Ist July to 30th August but some time premonsoon rain after 15th June influences major carp to reach their breeding grounds. In such situation it became very difficult to stop fishing due to lack of legal lacuna. Hence the imposition of close season should be observed from 15th June to 30th August. There is need to amend/ frame the rule accordingly.

☆ At present there is no awareness about conservation and sense of responsible fishery among the fishermen community. It is need of hour to create awareness about responsible fishery. This can ensure effective conservation and management of this reservoir. This can be achieved by (i) Developing consensus on this issue among various stake holders through generation of mass awareness (ii) Strengthening and empowerment of enforcement machinery for implementation of rules. (iii) involvement of non government organisations in the awareness programmes to make it more people friendly.

Table - 1. Yearly minimum/maximum water level (ft), water in flow/out flow and capacity (MCft) in Pahunj reservoir

Year July to June	Minimum water level	Water Capacity at minimum level	Maximum Water level	Water Capacity at maximum level	Water discharge through sluice	Total Water inflow	Water discharge through Canal	Total Water outflow
1994-95	753.1	35.962	767.0	577.032	90361.31	90938.342	541.070	90902.38
1995-96	740.8	5.244	762.0	308.991	-	308.991	303.747	303.747
1996-97	750.7	41.608	768.0	644.00	31072.199	31716.199	602.392	31674.591
1997-98	755.0	101.364	768.0	644.00	28873.25	29517.25	524.636	29397.886
1998-99	759.6	219.480	768.0	644.00	44048.918	44692.918	524.540	44473.438

(Mcft denotes Million cubic feet)

Table -2. Diurnal and Seasonal variation in Temperature (°c)

Month	Air Temp.at					Water Temp.at			
	Date	5-6hrs	9-10hrs	14hrs	17-18hrs	5-6hrs	9-10hrs	14hrs	17-18hrs
June' 95	11.06.95	31.0	33.5	48.5	39.2	28.0	31.0	36.0	24.2
July' 95	09.07.95	28.0	31.0	42.0	36.0	18.0	25.5	30.0	29.1
August' 95	10.08.95	26.0	29.2	42.0	33.0	20.0	25.0	28.0	28.0
September' 95	16.09.95	28.0	30.0	41.0	31.5	18.0	25.0	28.5	25.3
October' 95	19.10.95	22.0	27.0	38.0	30.0	18.0	24.5	27.5	26.0
November' 95	19.11.95	16.0	24.5	34.0	26.0	15.5	23.5	26.2	24.0
December' 95	24.12.95	11.0	16.3	26.0	18.0	16.2	17.0	24.2	15.5
January' 96	13.01.96	4.0	13.4	30.0	14.2	8.5	12.5	22.0	13.5
Febuary' 96	10.02.96	10.5	15.0	35.0	18.1	14.2	13.5	23.0	16.0
March' 96	10.03.96	16.5	20.2	40.0	21.0	15.0	18.3	24.0	19.0
April' 96	13.04.96	25.0	26.5	41.0	25.0	22.0	24.2	28.0	23.0
May' 96	11.05.96	28.0	30.5	46.5	34.0	26.0	25.0	31.5	29.0
June' 96	13.06.96	32.0	33.5	48.3	38.0	28.2	30.7	36.0	29.0
July' 96	13.07.96	26.0	30.0	43.0	35.0	20.0	28.1	29.4	28.2
August' 96	13.08.96	24.0	28.0	40.5	32.0	21.1	25.5	28.7	27.7
September' 96	14.09.96	21.0	24.3	37.5	28.2	19.0	20.7	28.0	25.0
October' 96	13.10.96	18.0	24.0	36.5	28.0	17.0	22.2	26.8	24.7
November' 96	20.11.96	16.5	22.8	34.5	26.6	15.8	22.0	26.0	24.2

Table - 3.Monthly Rainfall (in mm) Jhansi (1995-96)

	Month											
Year	April	May	June	July	August	September	October	November	December	January	February	March	Total
1989-90	0.0	00.0	34.3	146.8	478.7	008.8	00.0	00.0	00.7	00.0	042.3	001.0	713.6
1990-91	1.6	13.4	9.7	381.7	51.6	493.3	7.8	0.5	9.0	2.8	17.7	1.7	990.8
1991-92	9.0	0.2	12.4	460.3	428.6	2.8	00.0	12.7	9.5	4.0	00.0	000.0	939.5
1992-93	7.3	6.1	4.0	274.5	310.3	138.2	38.7	3.3	00.0	00.0	14.0	7.8	804.2
1993-94	0.5	55.1	31.5	187.2	16.1	342.3	1.8	00.0	00.0	15.8	2.0	000.0	652.3
1994-95	4.2	000	106.3	279.7	119.2	23.2	0.6	00.0	00.0	13.2	00.0	20.5	566.9
1995-96	2.6	00.0	60.6	360.2	211.0	155.2	00.0	00.0	06.6	43.4	10.8	000.0	850.4
1996-97	2.8	0.5	80.7	330.1	316.6	62.1	105.7	00.0	00.0	00.0	00.0	5.0	903.5
1997-98	21.4	17.0	50.4	171.8	280.9	147.7	108.3	29.1	159.3	NA	NA	NA	989.9

AverageAnnunal Rainfall =823.45

Table - 4. Monthly Average Relative Humidity (%)in Pahunj Reservoir

Year	April		May		June		July		August		September		October		November		December		January		February		March	
	Pd I	Pd II	Pd I	Pd II	Pd I	Pd II	Pd I	Pd II	Pd I	Pd II	Pd I	Pd II	Pd I	Pd II	Pd I	Pd II	Pd I	Pd II	Pd I	Pd II	Pd I	Pd II	Pd I	Pd II
1989-90	44	12	32	10	59	31	75	50	89	66	85	52	76	21	82	29	90	41	84	31	86	40	70	22
1990-91	45	17	48	21	63	37	86	69	86	55	90	65	85	34	86	30	91	40	90	48	89	35	79	24
1991-92	54	19	37	10	56	28	76	50	89	70	85	46	87	29	93	34	93	47	94	39	86	33	76	28
1992-93	60	24	40	24	54	25	82	54	95	74	90	61	89	40	91	41	91	37	93	40	83	42	84	33
1993-94	58	24	49	20	62	35	86	58	90	64	97	73	91	35	92	45	93	39	94	52	92	35	78	25
1994-95	64	23	49	23	59	44	93	76	94	76	87	53	86	27	94	27	94	29	93	49	94	55	82	29
1995-96	58	23	36	20	62	36	83	61	96	77	92	61	88	31	86	29	94	40	96	52	95	47	77	24
1996-97	50	14	44	19	59	35	89	70	96	80	93	59	92	45	94	27	96	30	95	36	91	32	66	29
1997-98	65	26	54	30	65	37	88	61	94	74	91	64	94	54	97	56	96	77	NA	NA	NA	NA	NA	NA

Table - 5. Monthly Average evaporation rate (mm)

Year	April	May	June	July	August	September	October	November	December	January	February	March	Average
1990-91	11.6	13.2	11.0	4.3	4.4	3.4	4.0	3.3	2.5	2.9	3.5	5.6	5.8
1991-92	9.3	12.9	13.0	8.8	3.4	4.8	4.2	2.7	2.0	2.4	3.9	6.1	6.12
1992-93	8.2	10.9	12.7	7.1	3.6	3.5	3.6	2.4	2.2	2.3	3.9	5.4	5.48
1993-94	8.7	11.5	9.7	5.5	4.3	3.6	3.7	3.2	2.0	2.0	3.5	6.2	5.32
1994-95	8.2	12.6	10.1	3.7	3.1	4.6	4.6	2.9	2.5	2.2	4.1	5.5	5.4
1995-96	9.0	13.9	12.6	6.8	3.4	4.4	4.3	3.6	2.5	2.1	3.9	7.1	6.13
1996-97	10.1	13.9	13.6	5.3	2.6	3.9	2.9	2.7	2.0	2.2	4.2	5.2	5.71
1997-98	7.7	12.1	12.1	5.5	3.5	4.2	2.9	1.9	1.1	NA	NA	NA	NA

Table - 6. Monthly Average wind velocity (Km/hr).

Year	April	May	June	July	August	September	October	November	December	January	February	March	Avarage
1990-91	7.9	10.9	11.2	8.9	6.1	6.5	3.4	3.7	3.7	4.0	4.5	4.9	6.30
1991-92	6.9	7.8	11.0	10.5	7.9	6.1	3.4	3.3	3.1	3.9	4.9	5.6	6.20
1992-93	6.1	8.0	10.6	9.0	3.6	3.4	3.0	2.2	1.9	2.7	3.9	3.9	4.80
1993-94	5.9	7.8	8.3	7.2	5.8	4.7	1.5	1.1	NA	NA	2.1	2.5	3.90
1994-95	3.7	5.6	7.5	4.6	2.3	1.8	0.5	-	0.7	1.5	2.1	3.1	2.78
1995-96	2.7	6.3	8.1	7.8	4.1	3.1	1.5	1.5	0.9	1.6	2.6	4.2	3.70
1996-97	4.5	7.9	9.6	9.8	2.6	2.5	1.6	0.8	0.3	1.1	2.9	4.0	3.60
1997-98	4.8	6.9	7.5	5.6	5.4	1.5	1.2	1.4	1.9	NA	NA	NA	NA

Table -7. Diel and seasonal values of pH and free Co_2 in Pahunj reservoir

		pH at				D Co2 (mg /l) at			
Month	Date	5-6hrs	9-10hrs	14hrs	17-18hrs	5-6hrs	9-10hrs	14hrs	17-18hrs
June' 95	11.06.95	7.2	7.8	8.5	8.2	3.0	2.0	NIL	NIL
July' 95	09.07.95	7.3	7.8	8.4	8.2	3.5	1.8	NIL	NIL
Aug' 95	10.08.95	7.8	8.2	8.7	8.4	3.2	2.0	NIL	0.8
Sep' 95	16.09.95	6.8	7.2	8.0	7.2	3.5	5.0	NIL	NIL
Oct' 95	19.10.95	7.3	7.5	8.8	7.5	3.5	2.0	NIL	NIL
Nov' 95	19.11.95	7.2	7.8	8.5	8.2	1.4	0.6	NIL	NIL
Dec' 95	24.12.95	7.8	8.6	9.2	8.5	1.0	NIL	NIL	NIL
Jan' 96	13.01.96	7.0	7.2	8.0	7.1	1.6	0.6	NIL	NIL
Feb' 96	10.02.96	7.2	7.0	8.8	7.5	2.2	2.0	NIL	0.4
Mar' 96	10.03.96	7.2	7.8	8.6	8.2	1.6	0.3	NIL	NIL
Apr' 96	13.04.96	7.6	8.4	8.8	8.3	2.0	0.8	NIL	NIL
May' 96	11.05.96	7.6	8.6	9.2	8.5	3.0	0.6	NIL	NIL
Jun' 96	13.06.96	7.7	8.3	8.8	7.2	2.3	NIL	NIL	0.3
Jul' 96	13.07.96	7.3	7.6	8.8	7.5	1.6	NIL	NIL	NIL
Aug' 96	13.08.96	7.2	7.8	8.2	8.4	3.6	2.0	NIL	NIL
Sept' 96	14.09.96	7.3	7.5	8.8	7.4	3.2	1.6	NIL	0.6
Oct' 96	13.10.96	7.0	7.2	8.0	7.2	1.1	NIL	NIL	NIL
Nov' 96	20.11.96	7.2	7.4	7.8	7.3	2.0	0.8	NIL	NIL

Table -8. Diel and seasonal values of Do_2 and Alkalinity (mg/l) in Pahunj reservoir

		Do_2 at				Total Alkalanity at				
Month	Date	5-6hrs	9-10hrs	14hrs	17-18hrs	5-6hrs	9-10hrs	14hrs	17-18hrs	AV
June' 95	11.06.95	1.8	2.6	6.8	6.1	105	133	130	110	119.5
July' 95	09.07.95	2.0	2.0	6.2	4.8	110	132	130	112	121.0
Aug' 95	10.08.95	2.5	1.9	7.0	3.2	112	140	135	120	126.75
Sep' 95	16.09.95	2.0	2.65	6.0	4.73	120	130	127	123	125.0
Oct' 95	19.10.95	1.9	3.4	6.1	5.5	160	203	136	161	165.0
Nov' 95	19.11.95	2.0	3.5	7.5	5.4	120	143	135	122	130.0
Dec' 95	24.12.95	2.5	4.5	5.5	5.2	100	105	104	100	102.25
Jan' 96	13.01.96	2.1	5.7	7.0	6.0	100	122	112	102	109.0
Feb' 96	10.02.96	2.2	5.4	6.5	5.5	102	105	130	122	114.75
March'96	10.03.96	1.8	5.3	6.8	7.1	102	130	120	105	114.75
Apr' 96	13.04.96	1.9	4.8	7.5	5.2	105	128	122	107	115.5
May' 96	11.05.96	2.0	2.8	6.5	4.8	120	136	128	118	125.5
June' 96	13.06.96	2.2	3.0	6.8	4.75	123	132	130	120	126.25
July' 96	13.07.96	2.5	2.9	4.5	3.5	102	128	115	105	112.5
Aug' 96	13.08.96	2.2	2.5	5.2	4.0	108	132	120	112	118.0
Sept' 96	14.09.96	1.8	2.2	5.5	4.35	105	133	128	107	118.25
Oct' 96	13.10.96	1.9	3.9	6.8	5.8	115	140	130	122	126.75
Nov' 96	20.11.96	2.4	4.5	8.9	8.0	105	130	125	110	117.5

Table - 9. Phosphate and Nitrate (mg/l) in Pahunj reservoir

Parameters	Jun' 95	Jul' 95	Aug' 95	Sep' 95	Oct' 95	Nov' 95	Dec' 95	Jan' 96	Feb' 96	Mar' 96	Apr' 96	May' 96	Jun' 96	Jul' 96	Aug' 96	Sep' 96	Oct' 96	Nov' 96
Phosphate	0.30	0.72	0.069	0.065	0.19	0.30	0.31	0.32	0.25	0.40	0.20	0.23	0.50	0.52	0.07	0.171	0.248	0.334
Nitrate	0.62	0.31	0.15	0.21	0.19	0.20	0.25	0.23	0.32	0.35	0.42	0.60	0.70	0.30	0.15	0.18	0.20	0.22

Table -10. Monthly abudance of phytoplankton (no/l) in Pahunj reservoir (from 1995-96)

Family	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Myxophyceae	926 (48.4)	760 (49.54)	365 (47.96)	140 (41.17)	173 (43.03)	403 (45.33)	588 (45.72)	492 (42.88)	470 (45.80)	360 (40.86)	261 (38.78)	556 (43.01)	549 (40.43)	398 (57.02)	257 (45.40)	179 (40.31)	366 (44.47)	505 (46.33)
Chlorophyceae	254 (13.28)	280 (18.25)	130 (17.08)	70 (20.58)	77 (19.16)	171 (19.23)	257 (19.99)	266 (23.17)	255 (24.85)	225 (25.54)	120 (17.83)	181 (14.23)	208 (15.31)	101 (14.47)	102 (18.02)	84 (18.92)	173 (21.02)	191 (17.53)
Bacillariophyceae	232 (12.12)	229 (14.93)	118 (15.50)	50 (14.70)	68 (16.91)	124 (13.94)	172 (13.38)	146 (12.72)	132 (12.97)	123 (13.96)	97 (14.8)	135 (10.62)	183 (13.47)	86 (12.32)	78 (13.78)	67 (15.09)	151 (18.34)	143 (13.12)
Dinophyceae	151 (7.90)	46 (3.00)	69 (9.06)	8 (2.35)	26 (6.47)	39 (4.3)	26 (2.02)	33 (2.88)	35 (3.41)	19 (2.156)	41 (6.09)	108 (8.49)	118 (8.69)	14 (2.00)	47 (8.3)	12 (2.7)	58 (7.05)	43 (3.95)
Euglenophyceae	350 (18.3)	219 (14.28)	79 (10.4)	72 (21.19)	58 (14.50)	152 (17.2)	243 (18.89)	203 (18.3)	132 (12.97)	154 (17.48)	154 (22.88)	292 (22.95)	300 (22.80)	99 (14.08)	82 (14.49)	102 (22.97)	75 (9.11)	208 (19.08)
Total	1913	1534	761	340	402	889	1286	1148	1026	881	673	1272	1358	698	566	444	823	1090

Figures in paranthesis represent percentage value of the total.

Table - 11. Monthy abundance of different phytoplankton genera (no./l) in phunj reservior.

Phytoplankton	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	Apri	May	Jun	July	Aug	Sept	Oct	Nov
1.*Microcystis*	316	249	111	44	75	141	126	113	125	110	71	165	190	91	78	57	165	166
2.*Phormidium*	34	80	27	8	10	17	8	–	–	05	–	13	21	28	20	11	22	19
3.*Osillatoria*	60	55	15	6	7	8	4	–	–	–	–	13	36	20	11	7	16	8
4.*Anabaena*	9	12	5	3	3	–	–	–	–	–	–	3	5	04	3	4	6	
5.*Merismopodia*	60	42	18	6	2	10	12	26	21	12	12	18	35	15	14	7	4	11
6.*Tetrapedia*	24	28	11	4	5	8	–	12	12	5	–	–	14	9	8	5	11	9
7.*Coelosphaerium*	388	267	164	65	70	211	425	341	302	210	166	302	228	222	115	84	142	283
8.*Nostoc*	24	27	9	3	–	8	6	–	06	13	6	12	14	9	8	4		9
9.*Spirulina*	11	–	–	1	1	–	5	–	06	05	6	10	06	–	–	–	-	-
10.*Scendesmus*	44	43	21	10	7	12	12	11	10	16	7	20	26	16	15	11	15	13
11.*Microspora*	–	31	10	6	15	31	18	–	–	–	–	19	–	11	7	7	33	34
12.*Pediastrum*	64	–	8	5	10	11	14	22	20	16	22	30	57	–	6	6	21	12
13.*Botryococcus*	–	30	18	7	13	12	16	17	16	17	11	–	–	11	12	9	30	11
14.*Coelastrum*	–	–	03	01	–	–	9	07	05	–	02	–	–	–	2	1	2	3
15.*Selenastrum*	27	28	14	6	5	9	10	08	08	12	10	24	21	10	10	7	11	10
16.*Tetraspora*	27	37	7	5	9	17	18	12	13	17	15	19	27	5	6	6	19	19
17.*Ulothrix*	–	–	–	5	1	–	28	24	18	11	5	45	–	12	24	6	3	1
18.*Protococcus*	65	79	33	16	11	61	115	148	149	121	43	–	53	–	–	21	25	68
19.*Spirogyra*	–	5	–	1	1	01	01	01	–	–	–	07	–	28	3	–	3	1
20.*Zygnema*	12	5	4	2	4	07	06	08	7	07	–	–	10	02	–	2	9	8
21.*Ophiocytium*	02	10	–	4	01	01	–	–	–	–	–	8	02	02	9	5	2	1
22.*Cocconeis*	13	12	12	2	–	09	10	08	7	8	5	09	12	04	8	3	-	10
23.*Amphora*	14	18	10	–	3	–	–	–	–	10	20	30	11	5	19	–	7	-
24.*Synedra*	48	46	26	5	6	11	20	17	22	18	16	05	39	6	–	6	13	12
25.*Stephanodiscus*	09	–	–	11	01	03	05	6	08	04	03	23	06	17	–	14	2	3
26.*Cyclotella*	34	43	–	–	4	11	14	13	11	09	12	30	16	–	20	–	9	11
27.*Navicula*	52	54	28	–	17	31	37	25	28	35	18	02	43	16	3	–	37	36
28.*Frustulio*	–	6	04	17	2	02	–	01	02	–	–	08	–	20	10	22	5	3
29.*Nitzschia*	19	23	13	–	9	17	25	32	18	17	11	31	15	3	5	–	20	19
30.*Melosira*	33	27	7	7	20	36	40	35	32	17	13	–	16	9	5	9	44	43
31.*Diatomo*	09	–	10	7	–	–	10	7	07	03	–	–	06	10	5	10	-	-
32.*Astreionella*	–	–	7	–	3	08	12	10	–	07	3	–	–	–	5	1	7	10
33.*Stauroneis*	03	–	7	3	–	–	–	–	–	–	–	6	02	–	5	4	1	2
34.*Gonatozygon*	11	12	6	–	3	5	09	–	5	03	01	–	9	–	4	1	6	4
35.*Docidium*	12	23	5	03	13	14	–	6	–	–	–	–	9	4	3	4	29	15
36.*Desmidium*	06	05	2	04	–	–	–	–	–	01	01	10	4	8	1	6	-	-
37.*Closterium*	133	18	62	01	13	25	26	27	35	18	40	98	105	02	43	2	29	28
38.*Euglena*	41	34	9	17	26	41	30	16	12	12	24	10	29	29	6	22	27	46
39.*Phacus*	309	185	70	55	72	111	213	195	120	142	130	282	271	70	76	80	48	162
Total	1413	1534	761	340	402	889	1286	1148	1026	881	673	1272	1358	698	566	444	823	1090

Table - 12. Monthly abundance of zooplankton (no/l) in Pahunj Reservoir

Specics			June' 95	July' 95	Aug' 95	Sep' 95	Oct' 95	Nov' 95	Dec' 96	Jan' 96	Feb' 96	March' 96	Apri' 96	May' 96	Jun' 96	July' 96	Aug' 96	Sept' 96	Oct' 96	Nov' 96
A	**Rotifers**																			
1.	*Brachionus*	*Calyciflours*	27	18	5	6	16	112	99	5	8	11	11	17	22	8	2	5	22	101
2.	*Brachionus*	*bidentata*	12	9	8	2	3						7	19	9	5	6	1	4	1
3.	*Brachionus*	*plicatilis*	61	17	17	12	14	106	95	30	24	31	107	35	31	7	10	8	19	97
4.	*Brachionus*	*havanaensis*	8	7	4	7	9	5	4					3	6	5	2	5	12	4
5.	*Brachionus*	*quadridentata*	6	6	3	4	14	30	26	2	2	13	5	17	5	4	3	3	20	28
6.	*Brachionus*	*angularis*	-	2	5	2	3	-	-	-	-	-	-	-	-	2	3	1	4	1
7.	*Keratella*	*canadensis*	7	9	6	5	10	-	-	-	-	-	-	-	6	4	4	3	14	-
8.	*Filinia*	*branchiata*	8	10	5	3	7	3	4	-	2	3	2	1	6	5	3	2	9	2
9.	*Filinia*	*longiseta*	5	3	5	3	7	-	-	-	3	2	1	11	4	3	2	2	10	1
10.	*Testudinella*	*sp*	19	18	6	12	14	2					4	9	17	10	4	7	19	1
	Total		153	99	54	56	97	258	228	37	35	60	137	115	106	51	36	37	133	236
B	**Cladoecrans**																			
11.	*Daphania*	*simillis*	3	-	-	6	15	16	13	5	30	43	60	90	20	-	-	-	20	15
12.	*Daphania*	*mangra*	2	3	-	4	-	-	-	-	18	45	75	58	2	2	2	3	1	
13.	*Ceriodaphnia*	*Cornuta*	69	40	20	8	30	85	84	-	-	21	35	150	51	18	12	6	41	78
14.	*Diaphanusana*	*specics*	80	7	10	19	30	90	-	-	15	14	37	18	40	3	6	14	40	82
15.	*Moina*	*sp*	11	3	5	2	5	7	2	5	10	13	25	22	15	5	3	1	6	6
	Total		165	53	35	39	80	198	99	10	73	136	232	338	138	28	23	24	108	175
C	**Copepods**																			
16.	*Cyclopes*	*strenus*	50	131	10	8	7	11	6	23	18	21	33	44	65	60	6	6	9	10
17.	*Cyclopes*	*Viridis*	125	240	42	30	40	150	138	27	23	31	172	160	102	118	25	22	55	136
18.	*MesoCylop*	*sp*	5	2	2	4	19	15	-	-	-	-	10	8	4	-	-	3	15	14
	Total		180	373	54	42	58	176	144	40	41	52	215	212	171	178	31	34	79	160
D	**Eggs & nauplii**		560	211	23	15	142	230	97	175	129	106	252	267	236	123	11	21	19	218
E	**Zooplankton**		1058	736	170	150	300	862	553	262	278	354	836	932	651	380	101	111	411	789

Table-13.Monthly abundance of Periphyton (no/cm²) from 1995-96

Family	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	Apri	May	Jun	July	Aug	Sept	Oct	Nov
Myxophyceae	41	-	-	-	-	75	289	172	227	363	469	195	-	-	-	174	450	652
(%)	42.15	-	-	-	-	40.0	35.25	38.28	58.35	37.00	33.26	31.45	-	-	-	56.13	47.39	40.50
Chlorophyceae	11	-	-	-	-	27	164	54	34	255	388	157	-	-	-	227	106	248
(%)	11.54	-	-	-	-	14.25	19.99	12.00	8.75	26.00	27.52	25.32	-	-	-	14.51	17.10	15.40
Bacillariophyceae	44	-	-	-	-	86	367	224	128	363	553	268	-	-	-	91	394	710
(%)	46.31	-	-	-	-	45.75	44.75	49.78	32.90	37.00	39.22	43.23	-	-	-	29.35	41.47	44.10
Total Number	96	-	-	-	-	188	820	450	389	981	1410	620	-	-	-	310	950	1610

Table - 14. Monthly abundance of Periphyton (no/cm^2)

Month & years	Numbers (u/cm^2)	Volume (ml)
June' 95	95	0.1
July' 95	-	-
August' 95	-	-
September' 95	-	-
October' 95	-	-
November' 95	188	0.2
December' 95	820	0.7
January' 96	450	0.4
Febuary' 96	389	0.35
March' 96	981	0.7
April' 96	1410	0.6
May' 96	620	0.3
June' 96	-	-
July' 96	-	-
August' 96	-	-
September' 96	310	0.25
October' 96	950	0.8
November' 96	1610	1.0
Average	435	0.3

Table - 15. Relative abundance of commercial species in Pahunj reservoir

Date/ Month	Catla	Rohu	Mrigala	Grasscarp	*Mystus spp*	*Wallago attu*	*Ompok pabda*	*Channa spp*	*Notopterus sp*	*Hetero penuestes fossilis*	*Labeo gonius*	*Puntius spp*	*M. armatus*	Total	gears used
30th June' 97	83	1	1	-	12	25	-	-	-	-	-	12	-	134	Gillnet
9th Sept.' 97	78	9	-	-	89	70	-	-	-	-	-	-	17	263	Gillnet
1st January' 98	12	129	116	-	27	9	-	-	6	-	4	-	6	303	Gillnet
26th March' 99	40	222	69	22	49	63	332	16	1970	67	73	27	-	2950	Gillnet
Total	213	361	186	22	177	167	332	16	1976	67	77	39	23	3650	-
%	5.84	9.90	5.10	0.60	4.85	4.57	9.10	0.44	54.14	1.84	2.11	1.07	0.63	100	-

Table - 16.Relative abundance of weed fishes in Pahunj reservoir

Sample	*Chanda spp*	*Rosbora daniconias*	*Osteobrama cotio*	*Glasogobius giuris*	*Xenetedon cancilla*	*Puntius sp.*	*Oxygastor bucaila*	*Labeo gonius*	*Prawn*	*Trichogaster faciatus*	*Total*	*Sample Area / Time*
1	116	75	-	51	30	115	15	3	1235	-	1640	Mid river/ Day
2	345	-	-	91	23	136	17	-	112	-	724	Dam site / Day
3	285	77	-	35	23	56	12	4	383	45	920	Parvaripura / Day
4	279	75	-	37	26	87	13	2	623	-	1142	Parvaripura / night
5	319	45	-	28	19	73	6	1	668	-	1159	Dam site / night
6	900	10	42	40	4	2	15	-	1438	20	2471	Dam site / night
Total	2244	282	42	282	125	459	78	10	4459	65	8056	
%	27.85	3.50	0.52	3.50	1.55	5.82	0.97	0.12	55.35	0.87	100	

Table - 17. Primary production, photosynthetic oxygen production and rate of respiration in Pahunj reservoir (Bottle suspension time 6 hrs.)

Month	Initial Oxygen mg/l (I)	Final Oxygen mg/l (L)	Final Oxygen in dark bottle mg/l (D)	Net Photosynthetic Oxygen production mg/l (L - I)	Gross photosynthetic oxygen production mg/l (L - D)	Respiration mg/l (I - D)	Gross primary production L - D x 312.5/6 mgC/m³/hr	Net primary production L - I x 312.5/6 mgC/m³/hr
June' 95	2.6	6.1	2.3	3.5	3.8	0.3	197.91	182.29
July' 95	2.0	4.8	1.9	2.8	2.9	0.1	151.04	145.83
August' 95	1.9	3.2	1.0	1.3	2.2	0.9	114.58	67.70
September ' 95	2.65	4.73	3.3	2.08	1.43	0.65	74.48	108.33
October' 95	3.4	5.5	3.0	2.1	2.5	0.4	130.20	109.37
November' 95	3.5	5.4	2.8	1.9	2.6	0.7	135.41	98.95
December' 95	4.5	5.2	3.1	0.7	2.7	-1.5	140.62	36.45
January' 96	5.7	6.0	4.0	0.3	2.0	1.7	104.16	15.62
Febuary' 96	5.4	5.5	4.5	0.1	1.0	0.9	52.08	5.20
March' 96	5.3	7.1	3.4	1.8	3.7	1.9	192.7	93.75
April' 96	4.8	5.2	3.0	0.4	2.2	1.8	114.583	20.83
May' 96	2.8	4.8	2.7	2.1	1.7	0.1	88.54	109.374
June' 96	3.0	4.75	3.3	1.75	1.45	0.3	75.82	92.84
July' 96	1.9	3.5	1.0	1.6	2.5	0.9	130.2	83.33
August' 96	2.5	4.0	1.9	1.5	2.1	0.6	109.37	78.12
September' 96	2.2	4.35	2.0	2.15	2.35	0.2	122.39	119.97
October' 96	3.9	5.8	3.1	1.9	2.7	0.9	140.62	140.62
November' 96	4.5	8.0	4.8	3.5	3.2	0.3	187.50	166.66

Table - 18. Fish production at corresponding water level in Pahunj reservoir

Year	Water level		Mean level	Fish production (Kg)
	Max(ft)	Mini(ft)		
1965-66	768.0	751.6	759.8	47860
1966-67	760.6	747.8	754.2	48703
1967-68	767.0	747.7	757.35	86274
1968-69	767.4	752.7	757.35	27384
1969-70	767.6	749.0	758.3	27886
1970-71	768.8	754.9	761.85	28631
1971-72	768.0	754.2	761.1	9690
1972-73	768.6	748.0	758.3	16860
1973-74	767.4	748.0	757.7	-
1975-76	768.0	742.5	755.25	11921
1976-77	767.5	751.0	759.29	16822
1977-78	768.0	751.8	759.9	16140
1978-79	767.5	748.0	757.75	19991
1979-80	758.0	752.0	755.0	4813
1980-81	766.5	747.5	757.0	22426

Table - 19. Fish production corresponding fishing days and effort in Pahunj reservoir

Year	Fishing days	Fish production (kg)	Fishing effort				
			No. of boats	Men	Castnet	Mahajal	Gill net
1965-66	126	47869	-	3059	1288	59	10400
1966-67	207	48703	1550	1271	389	91	3472
1967-68	157	8627	1350	817	65	45	586
1968-69	239	27384	1680	-	-	-	-
1969-70	193	27886	2450	2839	472	304	6663
1970-71	210	28631	2100	3102	168	541	4423
1971-72	124	9690	791	1784	206	126	3656
1972-73	146	16860	995	2976	48	140	7358
1973-74	124	24000	-	2296	-	272	-
1974-75	230	29364	-	3316	219	115	10092
1975-76	56	11921	-	1014	512	-	-
1976-77	134	16822	-	3222	-	279	-
1977-78	114	16140	554	2373	8	1140	37550
1978-79	83	19991	434	1785	82	8155	102725
1979-80	108	4812	458	1253	45	17208	101497
1980-81	38	22426	251	1531	-	19209	60580
Average	143	22569.2	788	-	-	-	-

Tabel - 20. Fish production and revenue in Pahunj reservoir

Year	Fish production (Kg)	Revenue (Rs)	Revenue (Rs/Kg)
1971-72	9690	17261.50	1.78
1972-73	16860	27554.83	1.63
1973-74	24000	40800.09	-
1974-75	29364	69485.70	1.70
1975-76	11921	33471.45	2.80
1976-77	16822	47751.81	2.83
1977-78	16140	38959.61	2.41
1978-79	19991	25991.31	1.30
1979-80	48131	16714.86	3.47
1980-81	22426	41289.00	1.841

Tabel -21. Total Fish yield, Fishing days and stocking in Pahunj reservoir

Year	Fishing days	Total production (Kg)	Fingerlings stocked	Fish Production/ha. (Kg)	Stocking/ha.
1965-66	126	47869	36300	92.37	70
1966-67	207	48703	120500	94.02	233
1967-68	157	8627	1191300	16.65	369
1968-69	239	27384	142783	52.86	275
1969-70	193	27886	377800	53.83	759
1970-71	210	28631	275158	55.27	531
1971-72	124	9690	415000	18.70	801
1972-73	146	16860	209000	32.54	403
1973-74	124	24000	227300	46.33	439
1974-75	230	29364	219230	56.68	423
1975-76	56	11921	215000	23.01	415
1976-77	134	16822	215000	32.47	415
1977-78	114	16140	207400	31.15	400
1978-79	83	19991	207500	38.59	400
1979-80	108	4812	210000	9.29	405
1980-81	38	22426	208000	43.29	401
Average	143	22569.19	279829	43.57	540

Tabel - 22. Estimation of absolute Fish yield/effort (Y/f) against absolute effort

Schaefer (r^2=0.49)		Fox (r^2=0.95)		Schaefer(r^2=0.18)		Fox (r^2=0.23)	
Effort (men/day)	Y/f (kg)	Effort (men/day)	Y/f (kg)	Effort (boat/day)	Y/f (kg)	Effort (boat/day)	Y/f (kg)
2	5615.500	10	1088.608	5	3630.774	5	2842.212
4	5035.830	20	893.43	10	3324.444	10	2291.100
6	4456.035	30	732.479	15	3018.11	15	1846.706
8	3876.24	40	601.093	20	2711.785	20	1488.568
10	3296.445	50	493.134	25	2405.455	25	1199.884
12	2716.65	60	404.5655	30	2099.125	30	968.49
14	2136.855	70	331.90	35	1792.795	35	779.866
16	1557.06	80	272.292	40	1486.465	40	628.422
18	977.265	90	223.387	45	1180.135	45	506.55
20	397.572	100	183.2663	50	873.866	50	408.312
21	107.57	110	–	55	567.472	55	329.126
22	–	–	–	60	261.146	60	265.298

Tabel - 23. Assessment of optimum yield and effort for Pahunj reservoir

Efforts	Average effort	Average annunal catch	Schaefer model			Fox model		
			MSY (kg)	F_{msy}	r^2	MSY (kg)	F_{msy}	r^2
Men/day 1970-71 to 1979-80	17.7 or 18 men/day	14623.000kg	331010	11 men/day	0.49	24658	50 men/day	0.95
Boat/day 1971-72 to 19-82-83 (except 73-74,74-75)	18.3 or 18 boat/day	15458.0kg	63252	32 boat/day	0.18	29904	23 boat/day	0.23

Tabel - 24. Maximum sustainable yield (MSY) Split up into feeding category for Pahunj reservoir year 1971-72, 1974-75 to 1976-77, 1989-90 to 1991-92 and 1995-96 to 97-98

Species/ feeding group	Toatl Weight of feeding group (kg)	Average weight per annum(kg)	% Composition	MSY split into feeding category(kg)	MSY (kg)
Planktivore					33101
Catla catla	16404.200	1640.420	7.34	2429.6	
Total	16404.200	1640.420			
Omnivore					
Labeo rohita	24012.500	2401.250	6.75		
L. bata	210.500	21.050	0.09		
L.calbasu	48.200	4.820	0.02		
L.gonius	8053.400	805.340	3.60		
Puntius spp	20881.350	2088.135	9.35		
Cirrhinus mrigala	16357.290	1635.729	7.32		
Other weed fishes	99130.700	9913.070	44.35		
Total	168693.940	16869.394	75.48	24984.6	
Third level Carnivores					
Wallagoattu	9327.700	932.770	4.17		
Channa spp.	3730.300		1.67		
Total	13058.000	373.030	5.84	1933.01	
Second level carnivore					
Mestacembalus	1577.700	157.770	0.70		
Mystus spp	17063.050	1706.305	7.64		
Ompok spp	1189.000	118.900	0.53		
Notoperus notoperus	5512.650	551.265	2.46		
Total	25342.400		11.34	3753.6	
Grand Total	223498.540		100.00		

Tabel - 25. Category wise fish production in Pahunj reservoir

Year	Fish production (Kg)	A(%)	B(%)	C(%)	D(%)
65-66	47860	8	4	44	44
66-67	48703	10.22	0.60	45	44.18
67-68	8627	7.60	-	51.6	41.6
68-69	27384	6.42	0.71	29.77	63.02
69-70	27886	5.80	0.36	52.2	41.34
70-71	28631	9.17	0.22	13.58	77.03
71-72	9690	12.50	0.09	27.02	60.39
72-73	16860	1.46	0.04	31.54	66.97
73-74	24000	6.35	0.009	33.55	60.1
74-75	29364	16.23	0.01	43.11	40.65
75-76	11921	10.20	5.1	35.3	49.4
76-77	16822	37.60	-	24.9	37.5
77-78	16140	30.42	-	39.15	30.43
78-79	19991	6.07	-	68.97	24.96
79-80	4813	30.01	0.003	15.77	53.517
80-81	22426	0.22	0.11	35	64.65

Tabel - 26. Category wise Fish production in Pahunj Reservoir

Fishing years	Total Fish Production kg	Category A		Category B		Category C		Category D	
		Wt.(kg)	%	Wt.(kg)	%	Wt.(kg)	%	Wt.(kg)	%
1989-90	16946.800	2129.100	12.56	8.400	0.049	6274.800	37.03	8534.500	50.35
1990-91	16994.200	2048.300	12.05	49.500	0.290	5713.400	33.61	9188.000	54.05
1991-92	16996.600	2059.100	12.10	35.500	0.210	9186.500	33.62	9186.500	54.06
1992-93	14896.750	3930.15	26.38	–	–	3517.100	23.61	7449.500	50.01
1993-94	13764.250	4111.900	29.87	–	–	4999.35	36.32	4653.000	33.81
1994-95	12594.000	1548.000	12.29	7.000	0.050	3632.500	28.85	7406.500	58.81
1995-96	13506.000	68.000	0.50	–	–	404.000	2.99	13034.000	96.51
1996-97	30138.200	2168.900	7.20	–	–	5987.400	19.86	21981.900	72.94
1997-98	73892.100	32253.100	43.65	–	–	6837.000	9.25	34802	47.10
1998-99	59836	16974.100	28.37	25.100	0.040	15336.800	25.63	27500	45.96

Tabel - 27. Species composition in Pahunj reservoir under royality system

Species	1971-72		1974-75		1975-76		1976-77	
	Wt.(kg)	%	Wt.(kg)	%	Wt.(kg)	%	Wt.(kg)	%
Catla Catla	76.500	1.05	619.750	2.60	116.600	2.91	1123.800	4.82
Labeo rohita	176.300	2.41	1169.850	4.90	820.300	20.50	4838.750	20.75
Cirrhinus mrigala	1118.310	15.34	2147.20	9.01	121.550	3.04	3549.100	5.22
Labeo calbasu	32.200	0.44	5.400	0.02	-	-	10.600	0.05
Ctenopharyndon	-	-	-	-	-	-	-	-
Labeo gonius	1873.800	25.71	680.700	2.86	-	-	89.700	0.38
Labeo bata	210.500	2.88	-	-	-	-	-	-
Cirrhinus reba	29.900	0.41	815.800	3.42	365.600	9.14	2741.500	11.75
Puntius spp	553.900	7.60	9765.700	40.49	1347.64	33.68	5272.650	22.60
Weed fish	-	54.79	-	60.7	-	69.27	-	70.75
Channa spp	223.400	3.06	2567.000	10.77	43.900	1.100	292.00	1.25
Wallgo attu	1028.400	14.10	891.600	3.74	220.200	5.50	732.700	3.14
Myustus spp	888.900	12.19	4492.700	18.85	252.000	6.30	2983.150	12.800
Ompok sp	75.200	1.03	573.500	2.41	7.200	0.18	28.100	0.12
N.notopterus	994.100	13.63	115.050	0.48	706.100	17.65	1662.200	7.120
M. armatus	11.00	0.15	-	-	-	-	-	-
Total	**7292.310**	**27.00**	**23834.250**	**21.74**	**4001.050**	**17.83**	**23323.250**	**20.04**

Tabel - 28. Species compostion in Pahunj reservoir (89-92) under Lump sum auction/Quota system

Species	1989-90		1990-91		1991-92	
	weight kg	percentage	weight (kg)	percentage	weight (kg)	percentage
Catla catla	808.600	4.76	266.500	1.57	872.100	5.49
Labeo rohita	514.800	3.03	210.100	1.24	365.500	2.30
C.mrigala	774.70	4.56	1524.000	9.02	855.500	5.39
H. fossiles	-	-	-	-	6.0	0.03
Labeo gonius	1824.400	10.74	1416.100	8.38	1167.200	7.35
Puntius sarana	1453.200	8.55	1442.500	8.53	1045.800	6.59
Other	9189.000	54.09	9189.00	54.36	8218.00	51.75
weed fishes	80.97		81.53		73.41	
Channa spp	59.000	0.35	226.800	1.34	274.500	1.73
Wallago attu	404.200	2.38	826.800	4.89	539.300	3.40
M. armatus	412.300	2.42	293.800	1.74	365.600	2.30
Ompok sp	115.500	0.68	52.000	0.30	275.000	1.73
Mystus spp	1209.400	7.12	1170.700	6.93	1202.100	7.57
N.notopterus	224.400	1.32	286.200	1.70	698.000	4.40
Total	**16989.500**	**100.000**	**16904.500**	**100**	-	-

Tabel - 29. Species composition in Pahunj reservoir under world bank scheme

Species	1995-96		1996-97		1997-98	
	Wt.(kg)	%	Wt.(kg)	%	Wt.(kg)	%
Catla catla	-	-	1829.450	6.13	10690.900	14.63
Labeo rohita	27.500	0.20	123.650	0.41	15766.750	21.58
Cirrhinus mrigala	40.500	0.30	308.33	1.03	5918.150	8.10
Labeo calbasu	-	-	-	-	-	-
Ctenopharyndon sp	-	-	-	-	80.200	0.11
Labeo gonius	73.500	0.54	759.500	2.54	168.500	0.23
Labeo bata	-	-	-	-	-	-
Cirrhinus reba	13034.000	96.41	20079.000	67.27	33803.000	46.26
Puntius spp	-	-	-	-	-	-
Weed fish	13175.500	97.45	23099.930	76.85	36624.500	76.28
Channa spp	2.500	0.18	8.200	0.03	33.000	0.05
Wallgo attu	96.500	0.71	1711.500	5.73	2876.500	3.94
Myustus spp	148.500	1.10	1851.000	6.20	2865.000	3.92
Ompok sp	46.00	0.34	-	-	16.500	0.02
Notopterus notopterus	2.00	0.01	257.700	0.86	562.500	0.77
Mestacembalus armatus	-	-	210.000	0.70	285.000	0.39
Total	**13505.000**	**10.45**	**29847.45**	**7.76**	**73066.000**	**5.10**

Tabel - 30. Summary of Hydrobiological parameters in Pahunj reservoir

Parameters	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Air Temp. (0^C)	31-48.5	26-42	26-42	28-41	22-38	16-34	11-26	3.9-30	10.5-35	16.5-40	25-41	28-46.5	32-48.3	26-43	24-40.5	21-37.5	18-36.5	16.5-34.5
Water Temp. (0^C)	28-36	18-30	16-28	17-26	19-34	14-32	9-22	8.5-24	15-30	14-35	22-36	25-37	28-36	18-29	17-30	15-28	20-33	22-22
Average pH	8.0	8.0	8.2	7.5	7.8	8.0	8.5	7.5	7.8	8.0	8.2	8.5	8.2	7.8	8.0	7.8	7.5	7.5
Transparency at 2 pm (cm)	18	20	25.5	35.0	48.9	55.4	58.3	60.6	55.7	53.5	67.0	75.3	80.2	85.5	25.5	30.2	45.2	47.3
Dissolved oxygen (mg/l)	1.8-6.8	2-4.2	2.5-5.4	2.65-5.5	1.9-8.1	2.0-7.5	4.5-5.2	2.2-6.5	2.0-6.5	3.0-6.8	3.75-7.5	1.9-6.5	3.0-6.8	1.9-4.5	2.4-5.2	2.4-5.5	1.8-6.8	2.8-8.9
Free carbondioxide (mg/l)	0-3.0	0-3.5	0-3.2	0-5.0	0-3.5	0-1.4	.3-1.0	0-1.6	0-2.0	.3-1.6	0-2.0	0-3.0	.3-2.3	0-1.6	0-3.6	0-3.2	0-1.1	0-2.0
Alkalinity (mg/l)	105-133	110-130	120-140	120-130	136-203	120-143	100-105	100-122	102-130	102-130	118-136	105-128	120-136	100-123	102-128	108-132	115-140	105-130
Phosphate(mg/l)	0.30	0.72	0.069	0.065	0.19	0.30	0.31	0.32	0.25	0.40	0.20	0.23	0.50	0.52	0.07	0.171	0.248	0.334
Nitrate(mg/l)	0.62	0.31	0.15	0.21	0.19	0.20	0.25	0.23	0.32	0.35	0.42	0.60	0.70	0.30	0.15	0.18	0.20	0.22
Zooplankton (%)	35.11	32.4	18.25	30.60	42.75	49.22	30.07	18.58	21.32	28.66	55.40	42.29	32.40	35.25	15.14	20.0	33.30	11.60
Phytoplankton (%)	64.7	67.6	81.75	69.40	57.25	50.78	69.93	81.42	78.68	71.34	44.60	57.71	67.60	64.75	84.86	80.0	66.70	88.40
GPP ($mgC/m^2/day$)	197.91	151.0	114.6	74.6	130.2	135.4	140.6	104.2	52.08	192.7	114.6	88.5	75.5	130.2	109.4	122.9	140.6	187.5
NPP ($mgC/m^2/day$)	182.3	145.8	67.7	108.3	109.4	98.9	36.4	15.6	5.2	93.75	20.83	109.34	91.1	83.3	78.12	119.97	140.6	166.6

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